COMBUSTION

Vol. 3, No. 10 APRIL, 1932 25c a copy

SAYREVILLE PLANT, JERSEY CENTRAL POWER & LIGHT COMPANY

Recent Extension at Porto Alegre, Brazil
By E. H. KRIEG

Solubility Studies of Boiler Waters
By FREDERICK G. STRAUB

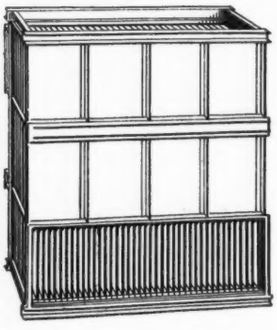
OTHER ARTICLES IN THIS ISSUE BY
W. S. PATTERSON • G. E. SAMS • A. J. MOSES • DAVID BROWNLIE • A. T. BROWN

These C-E Products Contribute to Efficiency of...

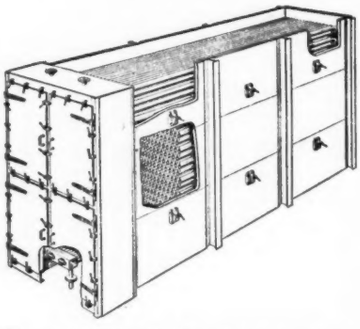
FORD PRODUCTION PROGRAM

Not only the merit of these individual pieces of equipment but also the skill with which they are combined accounts for the outstanding success of complete C-E Steam Generating Units such as those installed at the Rouge Plant of the Ford Motor Company—these are the largest high-pressure units in the world.

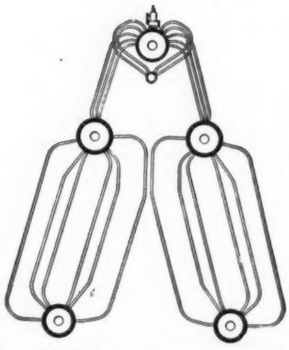
COMBUSTION ENGINEERING CORPORATION
200 Madison Avenue **New York N. Y.**



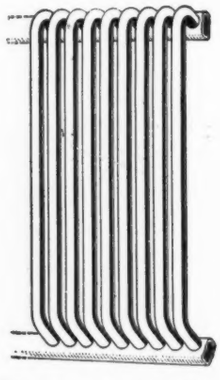
A—C-E Plate-Type Air Preheater



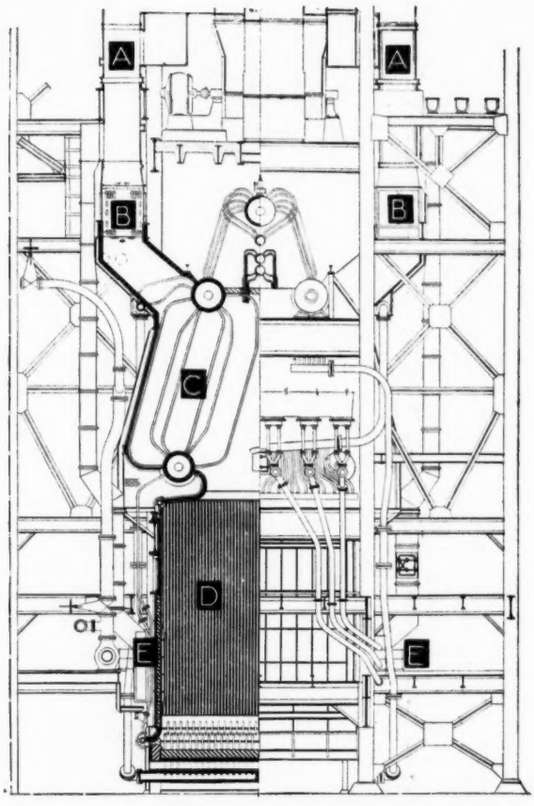
B—C-E Fin-Tube Economizer



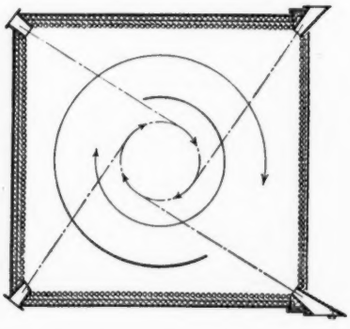
C—C-E Multi-Drum Boiler



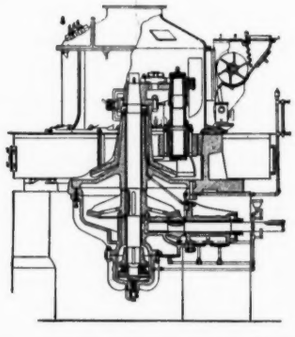
D—C-E Bare-Tube Water-Cooled Wall



One of two 1350-lb. C-E Units at Rouge Plant; 700,000 lb. capacity.



E—Lopulco Corner-Firing



Raymond Super-Mill of type installed at Rouge Plant

COMBUSTION

VOLUME THREE • NUMBER TEN

CONTENTS FOR APRIL 1932

FEATURE ARTICLES

Recent Extension at Porto Alegre, Brazil	*by E. H. Kreig*	7
Solubility Studies of Boiler Waters	*by Frederick G. Straub*	12
Anthracite Coal, Its Sources, Uses and Calculation of Air Requirements by Simple Graphical Method	*by W. S. Patterson*	17
Past and Present Developments of Water Gages	*by G. E. Sams*	24
History and Developments in the Art of Welding Ferrous Metals	*by A. J. Moses*	28
Combined Low Temperature Carbonization and Combustion	*by David Brownlie*	34
Some Notes on the Performance of Boiler Furnaces	*by A. T. Brown*	38
Continuous Weighing with Light-Sensitive Cells	*by E. J. White*	43

EDITORIALS

Modern Combustion Equipment Permits Wide Choice of Fuels 6

Economic Operation vs. Obsolescence 6

DEPARTMENTS

NEW CATALOGS AND BULLETINS 44

REVIEW OF NEW TECHNICAL BOOKS 45

NEW EQUIPMENT—Seamless, Flexible Metallic Tubing, Robotized Conveyor Scale, Eye-Line Water Level Indicator, Inverted Open Float Steam Trap, Lock-Forged Construction, Corrugated Expansion Joint, Non-Recording Pressure Controller 46

EQUIPMENT SALES—Boiler, Stoker and Pulverized Fuel 50

ADVERTISERS IN THIS ISSUE 51

H. STUART ACHESON, *General Representative* — CHARLES McDONOUGH, *Editor* — F. H. ROSENCRANTS, *Associate Editor*

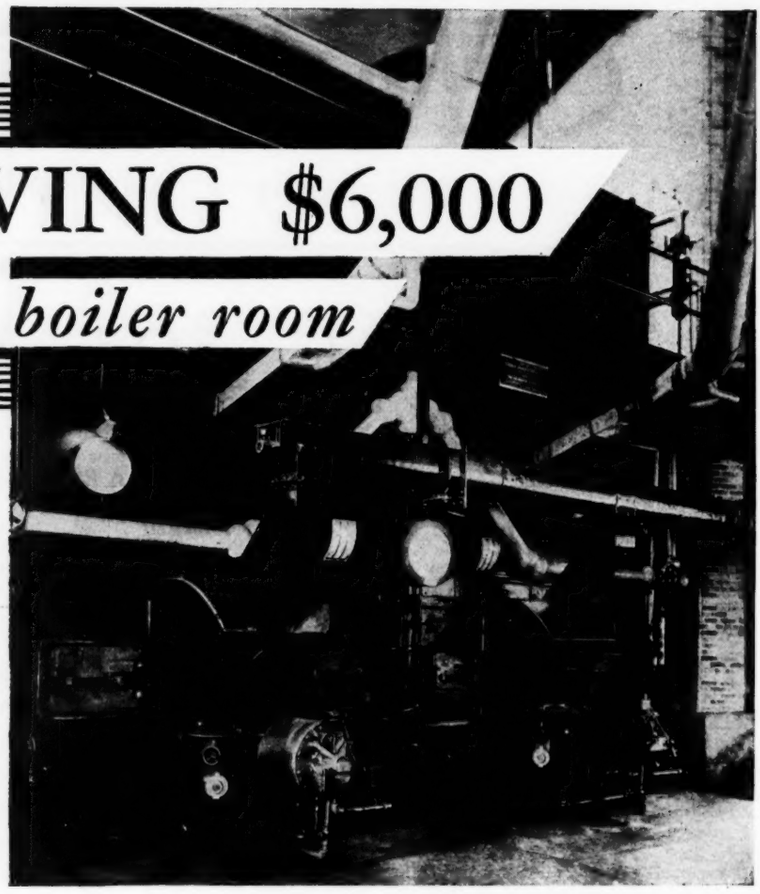
COMBUSTION is published monthly by In-Ce-Co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation, 200 Madison Avenue, New York. London office, Aldwych House, Aldwych, W.C.2. W. R. Wood, President; George H. Hansel, Secretary; W. I. Branigan, Treasurer.

SUBSCRIPTIONS, including postage, United States and Great Britain, $2.00 a Year. Canada $3.00 (includes Canadian tax). Other countries, $3.00. Single copies: 25 cents.

COPYRIGHT, 1932, by In-Ce-Co Publishing Corporation, New York. Printed in U.S.A. Publication office, 200 Madison Avenue, New York.

They're SAVING $6,000

in the boiler room



The two new 300-hp. boilers and Westinghouse single retort stokers. The furnace is designed to efficiently burn sawdust refuse in suspension, in addition to the regular coal fuel.

THROUGH the complete modernization of its power plant, the Milwaukee Chair Company of Milwaukee, Wisconsin, is saving $6,000 a year in boiler room bills alone. This saving represents $5,000 in the coal bill and the remainder in labor for fuel handling, firing boilers, etc.

This cut in boiler room costs is all the more significant because it has been achieved in the face of an increased consumption of process steam and by-product electric power.

The modernization program included, in addition to new auxiliaries, the replacement of three small hand-fired boilers by two new 300-hp. boilers, each of which is fired by a Westinghouse Single Retort Stoker. And as in many other industrial plants throughout the country, these stokers are of major importance in the economical operation of the boiler room.

The ability to handle heavy loads for long periods with high efficiency and low maintenance is an inherent characteristic of Westinghouse Single Retort Stokers. Write the nearest Westinghouse office for assistance in your coal burning problems.

Quality workmanship guarantees every Westinghouse product

Westinghouse

T 31691

# of largest boilers in the world...

The three units installed by Combustion Engineering Corporation in the East River Station of the New York Edison Company started operation as follows: No. 7—October 15, 1929; No. 8—November 7, 1929; No. 9—December 3, 1929. Since that time there has been no furnace maintenance on any of these units and the availability of all three furnaces has been 100 per cent. A recent inspection of the boiler units has shown that the tubes forming the water walls of the furnaces are in perfect condition despite the high rates of B. t. u. liberation which obtain when the units are operating at the higher capacities. Futhermore, there has been no slagging at any time on either the furnace walls or boiler tubes.

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE · · NEW YORK

PRODUCTS OF COMBUSTION ENGINEERING CORPORATION

BOILERS
Combustion Steam Generator
Heine Boilers
Ladd Boilers
Walsh-Weidner Boilers

STOKERS
Coxe Traveling Grate Stoker
Green Chain Grate Stoker
C-E Multiple Retort Stoker
Type E Underfeed Stoker
Type K Underfeed Stoker (for small boilers)
C-E Stoker Unit (for low-pressure boilers)

PULVERIZED FUEL SYSTEMS
Lopulco Storage System
Lopulco Direct Fired System

MISCELLANEOUS
Raymond Pulverizing Mills
C-E Water-Cooled Furnace
C-E Air Preheaters
C-E Economizers
C-E Ash Conveyers
C-E Ash Hopper

LITERATURE ON ANY OF THESE PRODUCTS WILL BE SENT UPON REQUEST

EDITORIAL

Modern Combustion Equipment Permits Wide Choice of Fuels

A FEW years ago furnace design and fuel burning equipment provided little flexibility with respect to type of fuel. Design was established and equipment selected for a particular plant with the expectation that a certain type of fuel would be used throughout the life of the installation. Then it was found that certain types of stokers were capable of burning a wider range of fuels than was previously thought possible. For instance, traveling grate stokers, originally designed for burning the small sizes of anthracite, were found to be capable of burning mine refuse, such as culm, and later were successful in burning certain non-coking bituminous coals and lignite.

In the meanwhile, pulverized fuel burning had passed through its early development stage and had proven itself to be the most versatile method of all.

Furnaces designed for pulverized fuel firing were suitable for either oil or gas and a few installations were designed for the use of all three fuels, either singly or in combination. With improvement in burner design, it was found possible to use any of these fuels with the same burner, simply changing the fuel nozzle and making certain adjustments.

While these various developments have all contributed to greater fuel burning flexibility, it is the progress of recent years in the design of furnaces and burners for pulverized fuel firing that has made it possible to design plants which can use solid, liquid or gaseous fuels with equal facility, and switch from one to the other with comparative ease.

With current over-production of oil and consequent low prices, this flexibility is particularly advantageous. The realization of this fact is evidenced by the number of pulverized-fuel-fired plants that are temporarily switching to oil or gas. In this connection, however, it should be pointed out that even though the immediate economies of such a change are considerable, and in most instances the cost relatively small, the decision is one that should be carefully reached. The present over-production of oil cannot long continue, and unless it is possible to arrange contracts on a price and time basis that will yield a large return on the cost of oil tanks, pumps, pipe lines, etc., the change should not be made. On the other hand, in localities where suitable contracts can be arranged for long-term periods, it is often possible to effect very substantial economies. Also, in the case of new plants, there are situations in which it may be advisable to include all the equipment required for the use of both coal and oil in the initial installation.

While pulverized fuel furnaces designed for all types of firing, i.e., vertical, horizontal and corner, appear to be equally adaptable to the use of oil or gas, experience to date indicates that the corner or tangential system of firing is the one most ideally suited to combination firing. The several articles published in recent issues of COMBUSTION on corner firing of solid, liquid, or gaseous fuels, either singly or in combination, evidence the pronounced flexibility of this method as well as its ability to maintain stable ignition over a wide range of heat liberation rates, even with such a lean fuel as blast furnace gas.

Economic Operation vs. Obsolescence

OBSOLESCENCE as it applies to steam generating units is being recognized in various ways. In some plants, where space is available for one or more additional boiler units, a new unit designed for high efficiency at high steam output is installed to carry the normal plant load, while the older units are maintained in stand-by service. An interesting example of this trend is the case of a large public utility which has recently installed a modern pulverized-fuel-fired unit with a capacity of approximately 500,000 lb. of steam per hr. in a plant containing 10 stoker-fired units. The new unit will normally carry the entire load with the older units available for peaks and when the new unit is out of service.

Other plants have installed new units designed for high sustained efficiency over a wide range of rating, which units float on the line, taking the fluctuations in load while the older units are operated continuously at their most economical rating.

For the most part, these possibilities are fully realized in public utility power plants and have either been taken advantage of or will be as soon as load conditions justify the capital outlay. But, strange as it may seem in these days when production economy is the chief concern of most manufacturing establishments, there are many fairly large industrial plants which are continuing to operate more or less obsolete units at uneconomical ratings. In cases where steam and power costs are an appreciable part of total production costs, the engineers responsible for steam production should feel it a paramount duty to thoroughly investigate the possibility of savings through replacement or supplementing of obsolete equipment. In such investigations, it will be found that recent development in the arts of combustion and steam generation will practically nullify the factor of normal working life of equipment.

Recent Extension at Porto Alegre, Brazil

The recent extension to the Porto Alegre Steam-Electric Station has several features of particular interest. The new boiler-and-furnace unit is fitted into a space originally provided for a boiler having one-fourth the capacity. Special provision is made for the collecting and disposal of fly ash. These and other features of the plant are discussed in the accompanying article, which also contains comparative maintenance and performance data on the new unit and the five units installed in 1928.

By E. H. KRIEG

Engineering Department

Electric Bond and Share Company

THE December, 1931, issue of COMBUSTION contained a description of the initial installation of two 5000-kw. turbine-generators and five 3500-sq. ft. boilers at the Porto Alegre Station of the Cia Energia Electrica Rio Grandense. The station with its accompanying sub-stations and distribution system was taken over as of May 1, 1928, by an affiliated company of the South American Power Company, a subsidiary of the American & Foreign Power Company, Inc., at which time the construction of the initial installation was not quite completed.

The initial installation was placed in preliminary operation in November, 1928, and, in July, 1929, work was started on an extension to include a 5000-kw., British-Thomson-Houston turbine-generator and one 9400 sq. ft., Combustion Engineering Corporation boiler. These went into operation November, 1930. This extension was necessitated by load increases and the desirability of shutting down several obsolete d.c. plants.

Many descriptions of stations that follow fairly well-established practices appear in various technical periodicals, but the recent extension of the Porto Alegre Station involved various conditions that ordinarily do not exist. These will be discussed in preference to a description of the equipment installed, although the main features of the equipment are tabulated at the end of this article for reference purposes.

Provisions for Eliminating Slagging and Removing Fly Ash

In the original five Sulzer boilers, difficulty is experienced when the coal contains over 8 to 10 per cent moisture, as slag forms on the refractory walls of the furnaces which are designed for a heat liberation of about 11,500 B.t.u. per cu. ft. per hr. at the maximum output of 30,000 lb. of steam per hr. or 8.5 lb. per sq. ft. of boiler heating surface per hr. Considerable trouble was also had in finding suitable material for the hammers of the old mills as they wore rapidly. The new mills are of the ball tube type.

The new boiler, sectional elevation of which is shown in Fig. 1, is equipped with bare C-E water-cooled walls, and no slagging difficulties have been experienced in either the bottom row of boiler tubes, the hearth screen, furnace, or the superheater.

The distance of 21 ft. from the burner tips to the hearth screen was carefully checked with the velocity of the primary air-coal mixture leaving the tip, to insure that the flame would not penetrate the hearth screen at high outputs. With an output of 116,000 lb. per hr., corresponding to 12.4 lb. per sq. ft. of boiler heating surface per hr., the flame just touches the hearth screen tubes. Although some secondary air is admitted through the ports in the air-cooled front wall, the flame is not thrust against the rear water wall and hence the ash particles do not adhere to any great extent. Little or no tertiary air is admitted around the burners.

At a boiler output of 116,000 lb. of steam per hr., about 21,000 lb. of coal are burned per hour; this forms, with 35 per cent ash coal, 7400 lb. of ash per hr. To remove as large as practicable a portion of dust from the flue gases, the following arrangements were developed.

As no dry-bottom pulverized coal furnaces ever catch more than 20 to 30 per cent of the total ash produced, it was anticipated that large ash accumulations would build up on the horizontal baffle below the third pass of the boiler. At first, a cast-iron screw conveyor was considered for removing such deposits continuously, but because of the estimated high temperature of the flue gas at this location which would cause high maintenance, the idea was abandoned. An arrangement of soot blowers was developed, so that the ash could be piled up on the portion of the baffle accessible from the access doors to facilitate removal by a hoe into convenient hoppers placed just outside the access doors on each side of the setting. From these hoppers the ash then drops through a large pipe into the main plant ash-sluicing system.

It was intended that no ash collect in any other portion of the boiler, breeching, air heater or induced draft fan connections, as it was desired to remove the ash in the ductwork after the induced draft fan so as to facilitate disposal. Ash is removed from the ductwork between the fan and the stack at high boiler outputs by a wet washer which has proved quite efficient. The ash washer consists of a brick duct, 5 ft. wide by 6 ft. high, with a concrete bottom which acts as a sluiceway. Corrugated asbestos board baffles are placed vertically with 5 in. between sheets, there being 12 sheets in the width of the duct. The nest of sheets extends 10 ft. 6 in. along the length of the duct; the sheets are 6 ft. high with the corrugations running vertically. Water is sprayed down over the sheets, washing the dust down to the sluiceway whence it goes to the station ash collecting pit. At light loads the wet washer may be by-passed to save the power required for the water pump and the extra power for the induced draft fan.

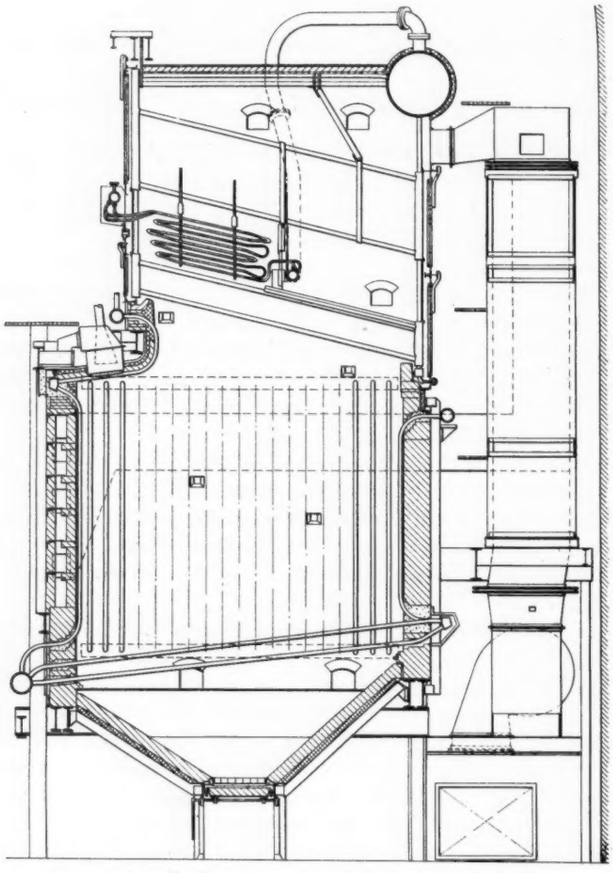


Fig. 1—Sectional elevation of new boiler and furnace.

The ashes collected at the base of the stack, which has an inverted conical shape, are also sluiced to the station ash pit. From this pit, the ashes are pumped about 1000 ft. through a pipe line and used for reclaiming a portion of the water front.

Economizers had been installed for the first five Sulzer boilers giving an average feedwater temperature of about 280 deg. fahr. to the boilers. However, in the extension, the feedwater is heated by bleeder heaters receiving steam from the first and fifteenth stages of the 18-stage turbine; a deaerating heater receives steam from the twelfth stage. The feed is heated to 350 deg. fahr. at full load and 315 deg. at half load. An air heater was installed for the purpose of providing sufficient hot air at about 380 deg. to the pulverizing mills, for mill drying purposes to permit the use of coal containing a high moisture content. There it is dried to a low percentage of surface moisture.

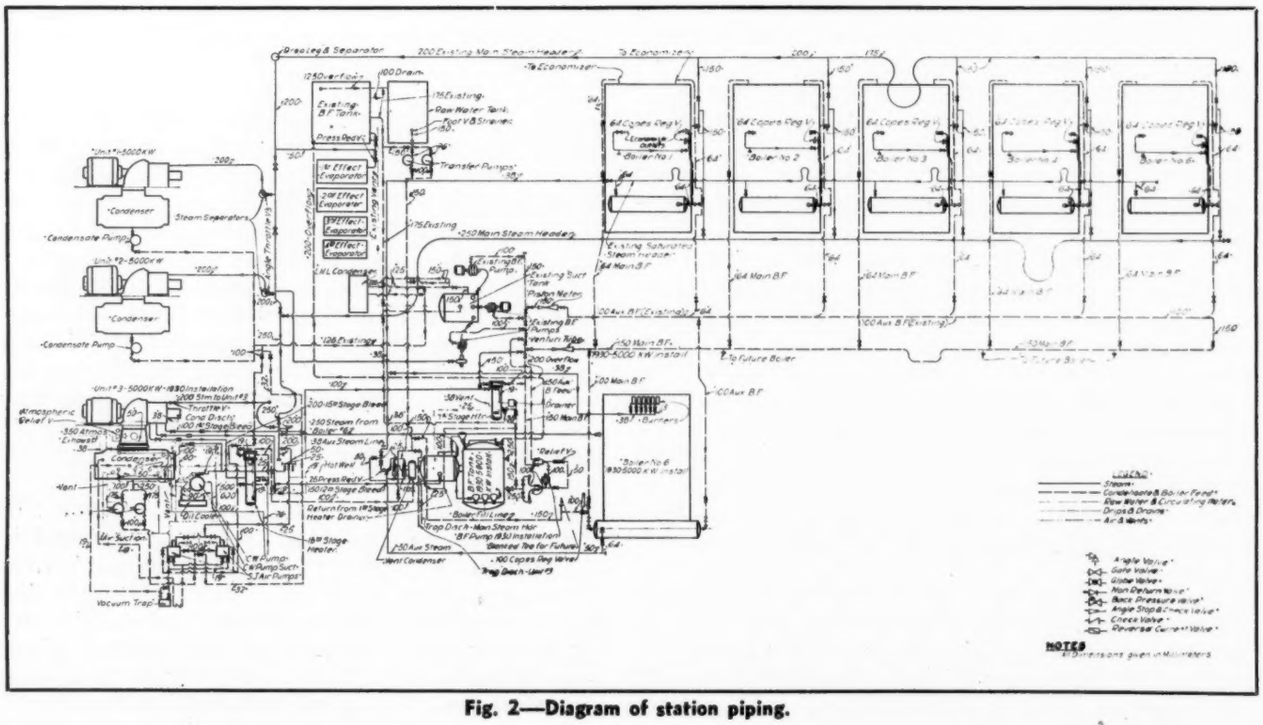


Fig. 2—Diagram of station piping.

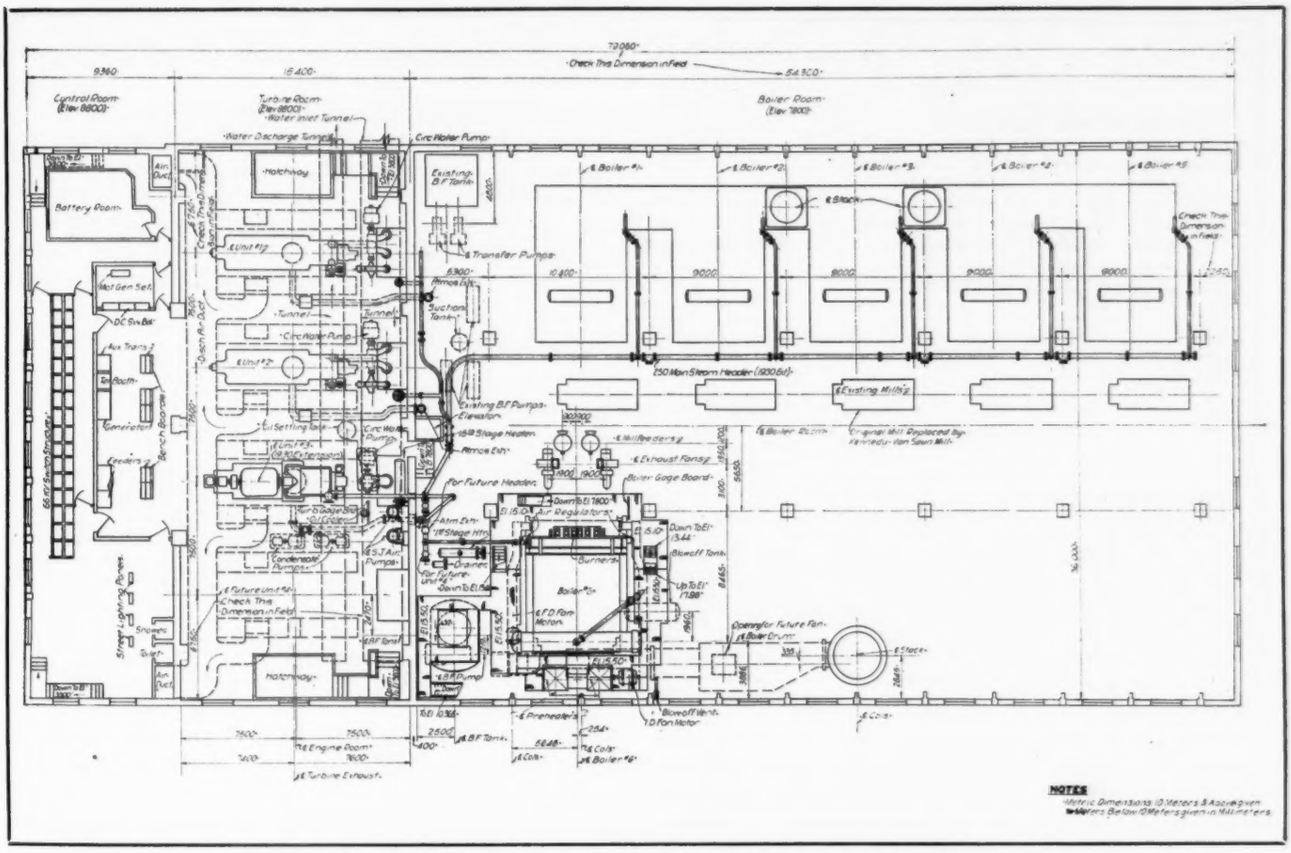


Fig. 3—Plan view of station showing arrangement of equipment.

Difficult Building Conditions

The existing building is of reinforced concrete construction throughout and the placing of the equipment was a major problem, as the new boiler had to be equal in capacity to four of the existing five boilers and fit into an area that was provided for a boiler one-fourth its capacity. This condition was inherited from the original design which contemplated that all future extensions should be the same as the initial installation. The boiler had to be entirely self-supporting, as no connections could well be made to the building structure and the latter could hardly be changed to eliminate interferences. Most of the foundation that had been installed for the anticipated future 30,000-lb.-per-hr. boiler was used for the new 116,000-lb.-per-hr. boiler; the only new foundations needed were for the air heater and the two pulverizing mills.

Although the original station was designed for throttle conditions of 285 lb. gage, and 660 deg. fahr., the new boiler and turbine were designed for ultimate conditions of 400 lb. gage, and 750 deg. fahr., in case the expenditure for providing dual pressure operation could be justified in the future. At present, it is undesirable to operate the station on two different pressures because proper spare capacity would not be had. The piping was so designed that the new boiler and turbine could be isolated from the existing plant without difficulty or outage when such operation should prove advantageous.

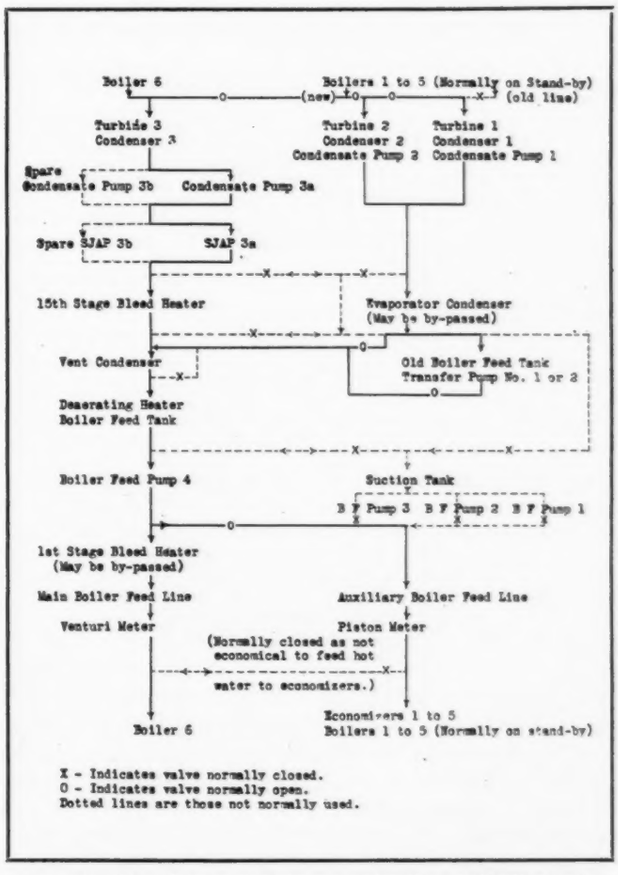


Fig. 4—Normal flow of steam, condensate and boiler feed.

CONDENSATE FLOW FROM UNITS 1 AND 2

NORMAL	UNUSUAL
Condensate pumps 1 and 2.	
Evaporator condenser (may be by-passed).	
Transfer pump 1 or 2 (existing boiler feed tank floats on this line). These pumps are necessary as condensate pumps 1 and 2 do not have enough head for pumping directly to the deaerating boiler feed tank.	
Vent condenser (may be by-passed).	
Deaerating head.	
Boiler feed tank.	
	At this point, condensate may be introduced from unit 3.
	Suction tank and boiler feed pump 4 (or 1, 2, or 3).
Boiler feed pump 4	
To boilers.	
	Suction tank and boiler feed pumps 1, 2, or 3.

BOILER FEED FLOW

NORMAL		UNUSUAL		
		Alternative 1		*Alternative 2*
Using boiler feed pump 4		Using Boiler Feed Pump 4		Using boiler feed pumps
For Boiler 6:	*For Boilers 1-5*	*For Boiler 6:*	*For Boilers 1-5:*	1, 2, or 3
1st Stage bleed heater (may be by-passed)	Auxiliary line	Auxiliary line	1st Stage bleed heater	Auxiliary or main header
Venturi meter	Piston meter	Piston meter	Venturi meter	Piston or Venturi meter
Copes regulator	Economizers 1-5	Auxiliary feed line	Main feed header	Auxiliary or main lines
Boiler 6	Copes regulators 1-5	Boiler 6	Economizers 1-5	Boilers 1-6
	Boilers 1-5		Boilers 1-5	

Fig. 5

Because the boiler feed and main steam piping were originally installed with too few sectionalizing valves, and were of lighter weight than standard American practice, new parallel lines were installed at the same time that construction on the extension was begun. The original piping was retained for emergency service.

To facilitate the routing of the condensate and feedwater, Fig. 4 was drawn to indicate the piping interconnections between the extension and the original equipment and to show which valves are normally open and closed. In superimposing a new design on an existing station, careful study is required to use the existing equipment to the greatest possible extent without lowering the combined station economy.

CONDENSATE FLOW FROM UNIT 3

NORMAL	UNUSUAL
From condenser hot-well to	
Either condensate pump 3a or 3b (one shut down).	
Either steam jet air pump 3a or 3b (one shut down).	
	At this point a connection is provided so that if units 1 or 2 are shut down, or if they are not supplying enough condensate to the evaporator condenser (low heat level condenser), unit 3 condensate may be sent thereto. This connection is also a by-pass when the deaerating boiler feed tank is out of service.
15th Stage heater (may be by-passed).	
	At this point unit 3 condensate may be sent to the evaporator condenser. In case the exit temperature from the 15th stage heater is low enough to give the desired quantity of make-up from the evaporator, this connection should be used in order to obtain the benefit from using the 15th stage heater.
	Unit 3 condensate diverted to the evaporator condenser may be returned as follows:
	Normal (Deaerating Boiler Feed Tank In) / *Deaerating Boiler Feed Tank Out*
	Evaporator condenser / Evaporator condenser (may be by-passed)
	Transfer pump discharge line / Suction tank
	Vent condenser / Boiler feed pump 4 (or 1, 2, 3)
	Deaerating head
	Boiler feed tank
	Boiler feed pump 4 (Pumps 1, 2, and 3 may be used) / Condensate may also be placed in existing storage tanks.
Through vent condenser (may be by-passed).	
Deaerating head.	
Boiler feed tank.	
	At this point condensate may be diverted to the suction tank and pumps 1, 2, or 3 if pump 4 is out of service.
Boiler feed pump 4.	
To boilers.	

Fig. 6

In case occasion demands a departure from usual operation, the tabulations, Figs. 5 and 6, prove of service.

Because of the difficulty in anticipating how the superheater would act under the expected conditions, space was left on the headers for adding 4 loops (176 sq. ft.) to the 44 loops (1935 sq. ft.) installed to raise the temperature in the future from the anticipated 670 deg. to 725 deg. fahr., and for two additional loops (80 sq. ft.) for correction purposes. This superheater, however, easily met the guaranteed figures over the entire range without taking advantage of the space left for the corrective surface.

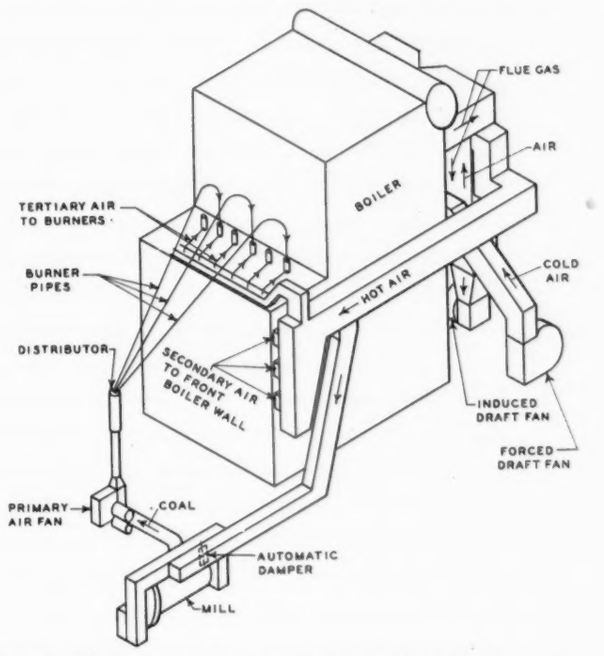


Fig. 7—Diagrammatic layout of ducts, pulverized fuel system.

Several tests have failed to show more than a trace of carbon in the ash caught in the furnace bottom and ducts.

The 1930 extension to the Porto Alegre Station was designed by the Engineering Department of the Electric Bond & Share Company. The engineers of the Brazilian Company, with the cooperation of the local official authorities, worked out the design of the fly ash washer using information obtained concerning similar installations elsewhere.

LIST OF MAJOR EQUIPMENT

Turbine-Generator: British-Thomson-Houston, Ltd., 5000 kw., 6,250 kva., 6,600 volt, 3,000 r.p.m., 3 ph., 50 cyc., 18 stage, with direct-connected, 125 volt, shunt-wound exciter.

Condenser: British-Worthington-Simpson, 5,700 sq. ft., two pass with non-divided water boxes.

Circulating Water Pumps: One British-Worthington-Simpson, 16 c.f.s., 22 ft. total head driven by 55 hp., B.T.H. squirrel-cage induction motor, 380 volt, 3 ph., 50 cyc.

Condensate Pumps: Two British-Worthington-Simpson, 60,000 lb. per hr., 170 ft. head, each driven by 17 hp. B.T.H. squirrel-cage induction motor, 380 volt, 3 ph., 50 cyc.

Pulverizing Mills: Two Kennedy Van Saun Mfg. & Eng. Corp., Type M, air-swept ball mills, 6 ft. 6 in. dia. by 10 ft. long, 15,000 lb. per hr., herringbone gear-driven by 150 hp., 480 r.p.m. constant speed slip-ring motor.

Mill Exhauster Fans:—Two Kennedy Van Saun No. 50, driven by 40 hp., 1450 r.p.m., variable speed G. E. motors.

Boiler Feed Pump: One A. S. Cameron Steam Pump Works, four stage, H.S.T., 125,000 lb. per hr. at 730 ft. head, driven by 200 hp., 3 ph., 50 cyc., 2880 r.p.m., G. E. constant speed motor.

Bleeder Feedwater Heaters for First and Fifteenth Stages: Foster Wheeler Corp.

Deaerating Boiler Feed Tank: Elliott Co., capacity 300,000 lb per hr.

COMPARATIVE PERFORMANCE AND DETAILS OF BOILERS

Boiler No.	6	1 to 5
Manufacturer	Combustion Engineering Corporation	Sulzer Bros.
Type	Horizontal, cross-drum	Sulzer-Garbe
Heating Surfaces, sq. ft.:		
Boiler	9400	3500
Superheater	1935 (interdeck)	1615 (convection)
Water Walls:		
Hearth screen	576	140
Side walls	725	...
Front wall	224	...
Rear wall	176	...
Arch	217	...
	1918	140
Economizer	....	2580
Air Heater	14,950	....
Furnace Volume, cu. ft.	7,350	3,913
Max. Steam Output, lb. per hr.	116,000	27,600
Max. Evaporation, lb. per sq. ft. per hr.	12.35	6.15
Max. B.t.u. liberated per cu. ft. per hr.	21,000	11,500
Mill Maintenance	about 11c per ton (includes fans, etc.)	about 19c per ton
Energy per ton, kw.	20	.....
Pulverizing Mills	2 per boiler	1 per boiler

Large Government Contract for Boiler Equipment Awarded

Combustion Engineering Corporation announces the receipt of contract from the United States Treasury Department, Washington, D. C., for 4-2500 hp. Walsh-Weidner Sectional Header Boilers and 4 C-E Multiple Retort Stokers, super-station type. This equipment is to be installed in the new Triangle heating plant, Washington, D. C., which plant will provide heat for the various buildings included in the new Federal building development.

In addition to boilers and stokers, the contract includes steel encased boiler settings, water-cooled furnaces, and forced and induced draft fans and drives.

The boilers are designed for 400 lb. pressure and are guaranteed for a production of 215,000 lb. of steam an hour continuous and 237,000 lb. maximum, from and at 212 deg. fahr.

The stokers will be 15 retorts wide, 45 tuyeres long, and will have a projected grate area of 480 sq. ft. each. They will be equipped with double-roll clinker grinders.

The government architect and engineers have designed this plant so that it will harmonize with the architecture of the surrounding buildings in the new development, and have taken particular pains to make it a model plant in every respect.

The consulting engineers on this project are United Engineers and Constructors, Inc., Philadelphia.

Solubility Studies of Boiler Waters*

By FREDERICK G. STRAUB

Special Research Assistant Professor
of Chemical Engineering,
University of Illinois

Approximately 2000 separate solubility tests have been made in the investigation being carried on at the Engineering Experiment Station, University of Illinois, to determine solubility data at the higher temperatures and pressures which data are to be used in ascertaining the causes of scale formation and methods of prevention. Professor Straub describes these tests and the equipment used in making them. Solubility data were taken over a range of temperatures corresponding to pressures from 150 to 1500 lb. gage. These data were taken under conditions of equilibrium, and, because of the possibility that equilibrium does not exist in all parts of a boiler and also because of the likelihood that factors other than solubility affect scale formation, the final tests have been conducted in an actual operating boiler designed for pressures up to the critical. The results of these tests should aid materially in explaining the reactions which occur in steam boilers at the higher pressures.

WHEN the tube shown in Fig. 1 failed, the plant operators started an investigation as to the cause of the failure. A survey of the location of this tube revealed the fact that it came from one of the water walls of a boiler operating at 700 lb. steam pressure. The blocks covering the tube in this area were burned away, thus exposing the tube to the direct action of the flames. The cause of the failure may have been flame impingement. However, when the tube was removed a small amount of scale was found in the area within a foot of the point of failure and only on the side of the tube exposed to the heat. According to one authority, the boiler water in use was classed as scale-forming in nature; according to another, it was not. Irrespective of its nature, this boiler had operated some three years practically scale free until this failure took place. The operators had felt that the water was not scale-forming until the trouble had developed, and then it was found practically impossible to classify the water because of different existing ideas as to what constituted a non-scaling bonler water at 700 lb. pressure. Some research had been done at pressures up to 175 and 200 lb. per sq. in.; but this was rather ncomplete and the conclusions drawn were not entirely in accord with operation.

In order to obtain data at the higher operating pressures and to clear up the question of what causes scale formation and what reliable methods may be used to prevent scale, the Utilities Research Commission of Chicago started a research project in the Chemical Engineering Division of the Engineering Experiment Station of the University of Illinois. The author has been conducting this investigation for the last two years.

The first part of the research program involved the obtaining of solubility data at the higher temperatures and pressures. With practically no available data above 200 lb. pressure and that available below this temperature very meagre, this information was essential. The obtaining of solubility data involves a large number of tests. If the tests had been run in a small boiler too much time would have been required. Consequently, the determinations were made in a large number of steel bombs. Four constant-temperature boxes were constructed to hold these bombs. With each box at a different temperature and with six bombs in each box, twenty-four separate solubility tests were run simultaneously, thus obtaining results much faster than possible by the older procedure.

The details of construction of the steel bombs are given in Fig. 2. Fig. 3 shows a photograph of the testing bomb completely assembled. Fig. 4 shows how the bombs are assembled in the heating box, while Fig. 5 shows three of the heating boxes in the foreground. The boxes are electrically heated by means of resistance wire. Constant temperature was maintained by means of automatic potentiometer temperature regulators. The accuracy of the temperature control was ±3 deg. fahr.

The procedure involved in these studies was to put the desired solid phase in the larger or bottom

* Part of research being conducted in the Chemical Engineering Division of the Engineering Experiment Station, University of Illinois, and financed by the Utilities Research Commission of Chicago. Released by permission of Dean M. S. Ketchum, Director of the Engineering Experiment Station.

bomb. The desired solution was then added boiling hot and the bomb closed by screwing the top on. The smaller or top bomb, previously cleaned and closed, was then attached by means of the connections on the capillary copper-lined steel tubing to the lower bomb. The valve between the two bombs was closed. The assembled bomb was put in the heating boxes and held at the desired temperature until equilibrium was obtained. In these tests the time in the furnace to reach equilibrium was found to be rather short—about 6 to 10 hours. However, the furnaces were run about 72 hours. Consequently, plenty of time was given for equilibrium conditions to be established.

When it was desired to sample the bombs, the valve was opened by means of the handle extending through to the outside of the heating boxes. The steam pressure in the lower bomb forced the solution through the filter and the capillary tube into the upper bomb. After the top bomb was filled with the solution, the valve was closed and the complete bomb was removed from the heating boxes. When cool, the top bomb was removed, and the volume of solution accurately measured and completely analyzed.

The solubility tests reported were run at 360, 405, 470, 540 and 600 deg. fahr., corresponding approximately to 150, 250, 500, 1,000 and 1,500 lb. gage.

The systems to be studied must be those which might possibly be encountered in a steam boiler. Thus, if the solid matter existing in contact with the water is referred to as the solid phase; the material in solution, as the liquid phase; and the steam or gases, as the gas phase, we have a simple method of classifying the systems we study.

Thus, if only calcium bicarbonate and sodium chloride are in our feedwater, the boiler would have at first calcium carbonate as a solid phase, sodium chloride and calcium carbonate in the liquid phase, and steam and carbon dioxide from the decomposition of the calcium bicarbonate in the gas phase.

In studying the various systems it was realized that apparently calcium would be present in the majority of the solid phases to be studied. The solid phase might contain calcium carbonate, hydrate, sulphate, phosphate, silicate alone or combined. The liquid phase would have the soluble sodium salts such as chloride, carbonate, hydroxide, sulphate, silicate, phosphate, etc.

A brief outline of the study which has been made is given as follows:

Solid Phase at start of test	Liquid Phase at start of test
$CaCO_3$	Na_2CO_3
$CaCO_3$	Na_2SO_4
$CaCO_3$	NaOH
$CaCO_3$	NaOH, Na_2SO_4
$CaCO_3$	NaOH, Na_2SO_4, Na_2CO_3
$CaCO_3$	NaOH, Na_2SO_4, Na_2CO_3, NaCl
$CaCO_3$	NaOH, Na_3PO_4, etc.

The same as the above would be run using calcium sulphate as a solid phase. Other tests would be run using calcium phosphate or silicate as the solid phase. The concentrations of the liquid phase must also be varied within the limits met in boiler operation. It will at once be evident that a large number of tests must be run, thus explaining why a large number of bombs were necessary. Approximately 2,000 separate solubility tests have been made. Each test involves analysis for an average of four different ions, such at OH, CO_3, SO_4, Ca, PO_4, SiO_2, etc. The

Fig. 1—Section of water wall tube which failed in 700 lb. pressure boiler.

results obtained to date are the summation of some 8,000 different results. These various systems are being studied in view of these available data. Part of the results were presented before the American Society of Mechanical Engineers in New York in December, 1931.

Theory of Scale Formation

The theories of scale formation which have been advanced have all been tied up with the question of relative solubility. Thus, Hall advocated the theory that calcium sulphate, decreasing in solubility with increase in temperature, caused the

precipitation of the sulphate at the heating surface as it became insoluble. With the data he had available he judged that calcium carbonate became more soluble at higher temperatures, and thus it would stay in solution at the heating surface and be precipitated in the cooler portions and form sludge. Thus, all one had to do was to determine the carbonate content which would cause calcium carbonate to form in preference to calcium sulphate. He then calculated the ratio of CO_3/SO_4 which must be maintained in a boiler to cause carbonate to form in preference to sulphate. When his calculations showed that sufficient amount of CO_3 could not be maintained in the boiler due to decomposition of the sodium carbonate to form hydrate, he concluded that phosphate was the best treatment at higher pressures.

Partridge supplemented Hall's theory with the bubble evolution theory of scale formation in which he puts forth the view that as the steam forms in the shape of bubbles on the heating surface, the thin edge of the solution, being supersaturated and in contact with the heated surface, causes rapid deposition of the excess dissolved material. His theory lays stress on the slope of the solubility curve of the particular salt in question. A salt decreasing rapidly in solubility would form scale faster than one whose rate of solubility decrease was less.

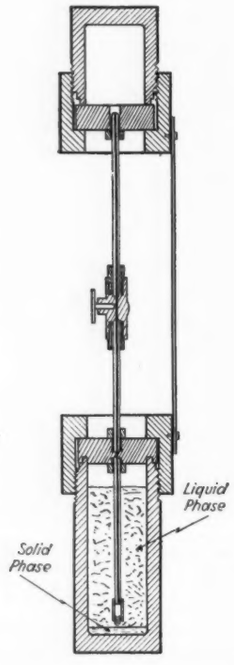


Fig. 2—Section of bomb used in solubility test.

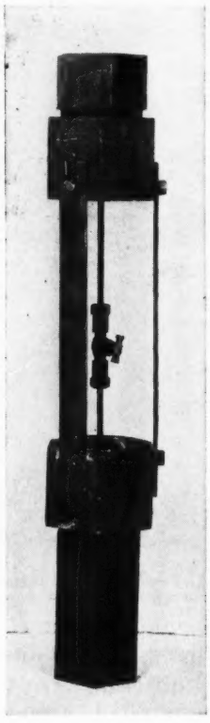


Fig. 3—Exterior of bomb shown in Fig. 2.

The solubility of calcium sulphate and calcium carbonate separately as determined in the present tests are shown in Figs. 6 and 7. Thus the calcium sulphate decreases very rapidly around 150 lb. pressure, 360 deg. fahr., and has a much slower decrease at 1500 lb. Calcium carbonate decreases very slowly but does decrease, and not increase, in solubility as the temperature increases.

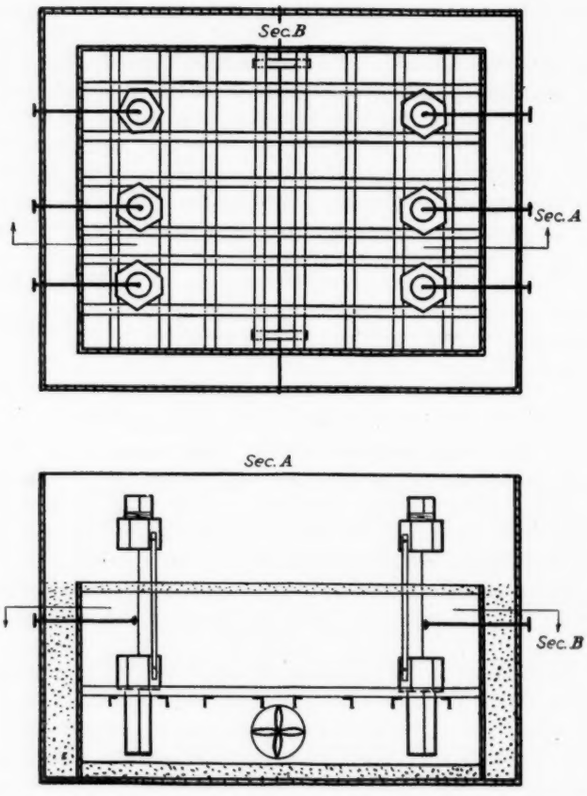


Fig. 4—Constant-temperature box, showing position of bombs.

When the effect of sodium hydrate or sodium carbonate on calcium carbonate was studied, it was found that the calcium carbonate solubility became zero when sodium hydrate or sodium carbonate was in the liquid phase. This proved to be very valuable information for it immediately gave an idea as to why carbonate scale does not normally form in a boiler but will scale up feed lines and heaters. The water coming to the boiler has some bicarbonate present or is supersaturated with calcium carbonate. The heating changes the soluble bicarbonate to less soluble carbonate, thus increasing supersaturation, and the calcium carbonate separates out. When it reaches the boiler proper, having sodium carbonate and sodium hydroxide present, its solubility is reduced to zero and it immediately precipitates out in the boiler as a sludge.

Irrespective of how the carbonate becomes non-scale forming, the fact remains that it is undoubtedly one of the desirable solid phases in the boiler. If the calcium sulphate, being scale-forming, could be converted to the carbonate, then the formation of sulphate scale should be prevented. This involves a study of the effect of sodium carbonate on the solubility of calcium sulphate. A detailed study was made of the CO_3/SO_4 ratio at tempera-

tures up to 640 deg. fahr. necessary to cause calcium carbonate to be the stable solid phase. It has been found that this ratio is decidedly low and it is apparently independent of the sulphate content. In other words, the maintenance of a fixed amount of undecomposed sodium carbonate in the boiler should prevent sulphate scale.

If a boiler has a small amount of calcium entering in the feedwater the calcium will slowly concentrate. However, if sodium hydroxide is present the calcium solubility drops to zero and it remains in the sludge unless there is already some calcium sulphate in the sludge.

If calcium sulphate is present, then a small amount of sodium carbonate will convert it to calcium carbonate, whose solubility is zero. Our tests always showed that when a slight excess of sodium carbonate was present over that amount necessary to react with the calcium sulphate in the solid phase the resulting calcium carbonate formed was insoluble. Similar tests have been

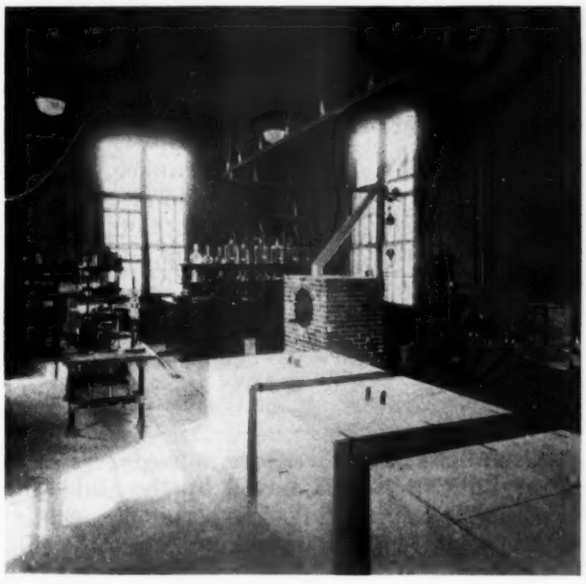


Fig. 5—View of laboratory showing three of the heating boxes in the foreground.

run with a mixed solid phase of calcium carbonate and calcium sulphate with similar results.

These results all indicate that soda-ash treatment, when properly controlled, should prevent calcium sulphate scale at pressures up to 1500 and 2000 lb. without causing high alkalinities and without interfering with the maintenance of the recommended embrittlement ratios.

Phosphate in the liquid phase gave results similar to the carbonate.

The main scale problem which the higher pressure plants are encountering appears to be silica scale. A study of the influence of sodium hydrate on the solubility of calcium silicate gave results which indicated that the silicate was not made soluble by the addition of reasonable concentrations of sodium hydroxide. The calcium solubility of calcium silicate in the presence of sodium carbonate and sodium hydrate is zero. Thus, the calcium silicate, once it forms on the heating surface, cannot be readily removed by

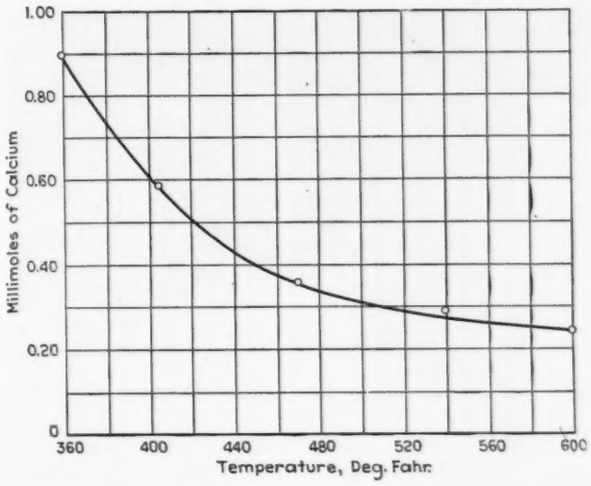


Fig. 6—Solubility of calcium: solid phase added, calcium sulphate. (Millimoles x 40 = parts per million of calcium)

the addition of carbonate or hydrate. However, the silicate will exchange on the heating surface with other scale. Thus calcium sulphate may be formed and when sodium carbonate or hydrate is added, and if sufficient silicate is present in solution, the scale will change to calcium silicate which will remain on the tube.

The tabulation of the available data should do a great deal toward answering large number of questions as to what should and does happen in high pressure steam boilers. However, it should be realized that the solubility data are taken under conditions where equilibrium exists and it is possible that true equilibrium does not exist in all parts of a boiler. It is also entirely possible that the solubility is but part of the story and that the rate of heat transfer at the heating surface may be the controlling factor in the rate of scale formation.

The final test must apparently be made in an actual operating boiler. The author has built and

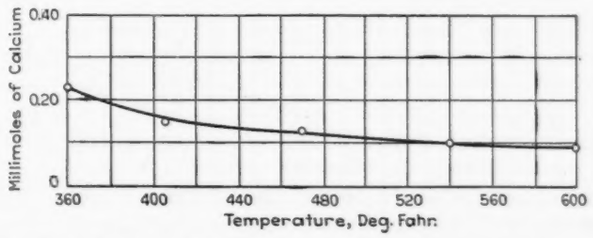


Fig. 7—Solubility of calcium: solid phase added, calcium carbonate. (Millimoles x 40 = parts per million of calcium)

now has in operation a one-tube scaling boiler capable of being operated at pressures up to the critical. Fig. 8 shows the boiler and its accessories. The steam is generated in the scaling tube with a rate of heat transfer up to 100,000 B.t.u. per sq. ft. per hr. The concentration of the solu-

tion going to the tube is under close control. The rate of heat transfer and the rates of formation of the various scales are also being studied, and

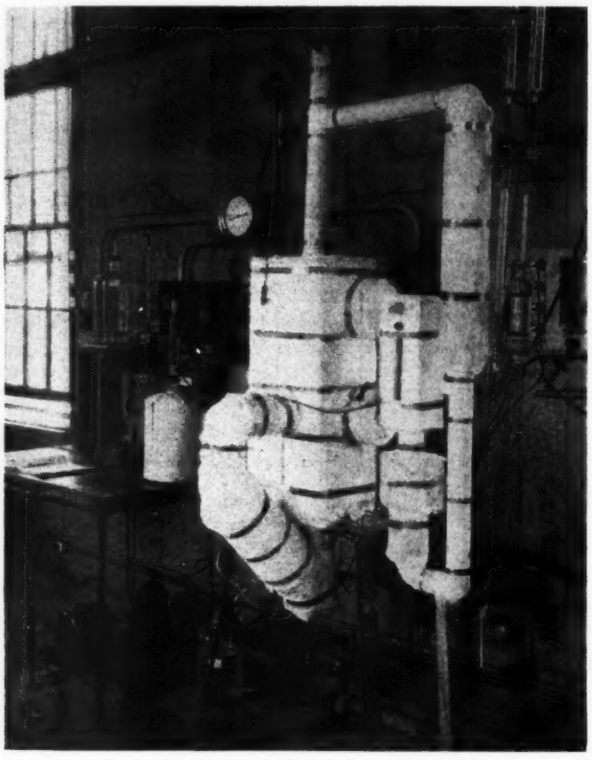


Fig. 8—Boiler used for scaling tests.

these will be correlated with the solubility data already collected. In this manner it is hoped that the mystery will be removed from the reactions occurring in steam boilers at higher pressures.

●

Eight Engineers of the General Electric Company share in the Awards under the Charles A. Coffin Foundation which was established by the Company in 1922 as a tribute to its first president. The engineers receiving the Awards for constructive ideas, some of which were concerned with electric welding, are Karl B. McEachron, L. H. Whitney, J. R. T. Craine and Frank M. Clark, of Pittsfield, Mass.; Marion A. Savage, and C. A. Nickle, of Schenectady; E. H. Horskotte, of Erie, Penna.; and William A. Lewin, of Chicago.

●

Lincoln Electric Company, Cleveland, Ohio, announces the appointment of B. F. McIntyre to its Chicago office and of Fred Archer to its Philadelphia office. Mr. McIntyre was formerly with the Industrial Controller Company and Mr. Archer was formerly president of Fred Archer, Inc.

Hoover portrait presented to Engineering Societies

A large portrait of President Hoover, painted by the internationally known artist, Philip A. de Laszlo, was unveiled at a meeting of the United Engineering Societies Trustees in the Engineering Societies Building on February 15. The President, who is an honorary member of the Civil, Mining and Metallurgical, Mechanical and Electrical Engineers Societies, and formerly president of the American Institute of Mining and Metallurgical Engineers, sat for this portrait in response to a request from these societies.

The portrait will hang permanently in the Engineering Societies Building. It was unveiled by Ambrose Swasey, Past-President of the A.S.M.E., and was presented by Gano Dunn, chairman of the Hoover Medal Board of Award, representing the four societies, to the United Engineering Trustees, as custodian. The portrait was accepted by H. A. Kidder, President of the United Engineering Trustees.

●

Harnischfeger Corporation, Milwaukee, has recently acquired the arc-welding and electric motor line of Northwestern Manufacturing Company, and will manufacture the products at its National Avenue plant. H. L. Hansen, inventor of this welding equipment has joined the Harnischfeger Corporation in a consulting capacity.

●

The Usefulness of Mathematics to Engineers is the title of Bulletin No. 27 issued by the Ohio State University, Engineering Experiment Station, Columbus, Ohio. Anyone contemplating the study of engineering will find this pamphlet very useful. The article by Prof. P. W. Ott, Associate Professor of Mechanics, The Ohio State University, was originally published in the Ohio State Engineer, and brings out clearly the usefulness of mathematics to engineers. This bulletin may be obtained direct from the Ohio State University.

●

Technical Dictionary—English-German-Italian—a collection of technical terms from metallurgical, foundry, factory and workshop practice. This is a pocket dictionary, compiled as concisely as possible. Will be useful to the engineer or technically-minded business man in reading German or Italian technical periodicals. Contains 420 pages, including conversion tables. Size, 6⅛ x 4⅜, bound in gray cardboard. May be obtained direct from the publisher, Hubert Hermanns, Berlin-Lichterfelde-West, Dahlemerstr. 63a, Germany. Price 15 shillings.

Anthracite Coal—Its Sources, Uses and Calculation of Air Requirements by Simple Graphical Method

By W. S. PATTERSON

Combustion Engineering Corporation, New York

This article supplements the author's previous paper in the February issue of COMBUSTION in which a chart for calculation of air requirements and combustion products of all U. S. coals except anthracite was presented. A similar chart for anthracite appears on page 21 of this issue. The author has, in addition, presented some interesting information on anthracite and super-anthracite which he has collected and consolidated from the writings of numerous authorities.

COAL has been classified in numerous ways depending on the point of view of the investigator interested in such classification. Thus a scientist would naturally classify it according to his knowledge of its chemical composition, its origin from plant life, or its geological age; a combustion engineer might classify it according to proximate analysis, burning characteristics, or physical characteristics; a commercial organization might classify it according to use, geographical source, coal bed, and endless other trade designations.

The classification of coal by name and volatile content as given in Table I of the author's article in the February issue of COMBUSTION is therefore only one of many classifications. It is based upon the observation that as the geological age of the coal increases its volatile content decreases. Based on its proximate composition anthracite is lowest in volatile content, the dry coal generally containing less than 7 per cent. This classification includes also super-anthracite or graphitic coal which cannot be distinguished from anthracite merely by its volatile content, but is quite different in many other respects and must be treated separately for this reason.

Geologically, anthracite and super-anthracite are of the highest "rank," representing the last stage of decay of vegetable matter and therefore probably the oldest deposits of coal. Classified according to proximate analysis, their volatile content is lowest, and according to ultimate or chemical analysis their carbon-hydrogen ratio, C/H, is highest of all coals. Physically they are very hard and heavy, their specific gravity varying between 1.4 and 1.8.

In contrast to the above mentioned similarities, anthracite has glossy black surfaces while super-anthracite has a dark gray color resembling graphite. The volatile content of anthracite contains considerable hydrogen while that of super-anthracite contains very little but is mostly inert gases which do not support combustion. A good grade of anthracite will have less than 10 per cent ash content and a heat value of about 14,000 B.t.u. per lb., dry basis, while the best super-anthracite, judging from Bureau of Mines analyses in Bulletin 22 will have 15 to 20 per cent ash content and a heat value of only 11,000 to 11,500 B.t.u. per lb., dry basis. Also the moisture content of the super-anthracite is much higher than anthracite. The difference in hydrogen and ash content between these two coals is shown graphically in Fig. 1.

Sources and Resources of Anthracite

In the United States, super-anthracite or graphitic coal is found principally in Rhode Island. Anthracite is found in Pennsylvania, Colorado, Utah, New Mexico and Washington. The low volatile coal of Arkansas and Virginia is nearly all of semi-anthracite rank having volatile content of about 10 per cent, dry basis. It has been estimated by the U. S. Bureau of Mines that the anthracite fields of Pennsylvania originally held about 21 billion tons of this fuel and that about 17 billion tons still remain. In addition there is in Virginia, Arkansas and Colorado about 1.4 billion tons of coal of anthracite type. This however is softer and not comparable in quality to the Pennsylvania deposit although some of the Colorado anthracite is extremely low in ash and high in heat value as evidenced by several of the points plotted on Fig. 1, from U. S. Bureau of Mines analyses. The Pennsylvania Geologic Survey estimates that Pennsylvania has produced 5.5 billion tons of anthracite. This has been mined during the past 100 years but the present annual production ranges from 80 to 85 million tons a year at which rate over half the estimated remaining supply would be consumed in another hundred years.

Burning Characteristics and Uses of Anthracite

Burning characteristics and use are definitely related to each other in any coal but particularly so in the case of anthracite. Here again, however, we must discuss super-anthracite and anthracite separately.

In the former, the Rhode Island graphitic coal, the high percentage of ash contained in the fuel is

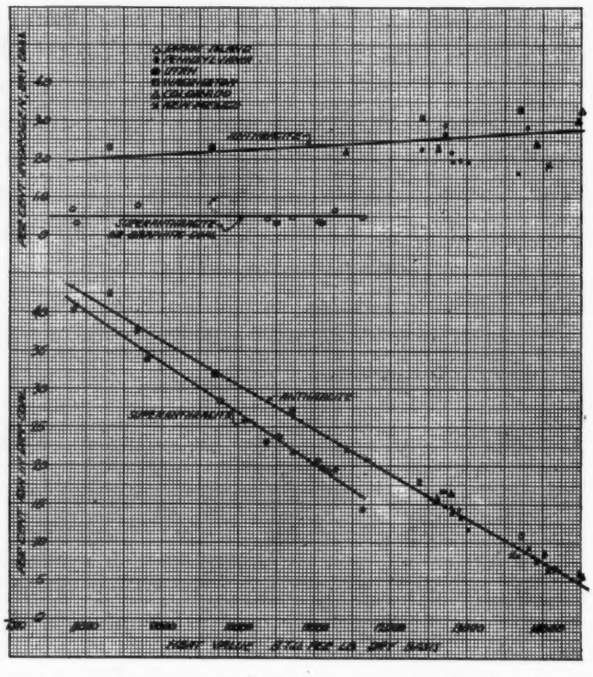


Fig. 1—Comparison of anthracite and super-anthracite showing relation of hydrogen and ash content to heat value. Plotted from U. S. Bureau of Mines Analyses in Bulletin 22.

uniformly distributed through the coal and blankets the combustible ingredients when the coal is burned on a grate. It therefore burns very slowly and because of its low volatile content, consisting mostly of inert gases, has practically no flame. It burns best when crushed into small pieces not greater than 1 in. or 1½ in. in size and with a thick fuel bed and forced draft. It may be burned on hand-fired grates and forced-draft traveling-grate stokers.

Attempts to burn this graphitic coal in pulverized form have met with only partial success due to inability to maintain ignition even in solid refractory furnaces. It can however be ignited and burned when mixed with an equal weight of the semi-bituminous coal which is almost exclusively used for steaming purposes in the New England territory.

At present Rhode Island super-anthracite is not used as a steaming fuel for power plant boilers and only to a limited extent for domestic heating.

Pennsylvania anthracite also burns with a short, nearly transparent, smokeless flame and does not change size or shape during combustion. The larger sizes burn readily on hand-fired grates without requiring much draft and any desired rate of combustion may be obtained by simply regulating the air flow. It has aptly been called "the aristocrat of fuels" because it is incomparable for domestic purposes.

Pennsylvania anthracite was originally used entirely for domestic house heating and cooking and, to go back 100 years, the anthracite used was about 90 per cent of the total coal mined in the United States. At the present time the annual production of anthracite is about 17 per cent of the total coal production and of this about 80 per cent of it is shipped as domestic size coal.

It is therefore evident that owing to the demand for the larger sizes for domestic fuel and the high price it brings, only the very small sizes can be used for steaming fuel under power plant boilers. In this form the fuel is generally burned on forced-draft travelling-grate stokers of the Coxe type. Fig. 7 shows a setting arrangement of this type of stoker suitable for burning small size screened coal or silt. The former is never shipped to any great distance and the latter is only burned at or very near the mines.

Anthracite has been successfully but not extensively burned in pulverized form. Silt and river coal have both been used in this form at or near the source of supply. Anthracite is hard to pulverize, and hard to ignite due to its low volatile content. Powdered anthracite burns with very little visible flame but with many visible particles of incandescent coal and owing to the length of time required for complete combustion of these particles the heat loss due to unburned carbon may be as much as four times greater with pulverized anthracite than with any other pulverized coal.

Sizing of Anthracite

A standard sizing classification of anthracite is given in Table I. By mining engineers those sizes larger than pea are termed "prepared" sizes and the pea size and smaller are called "steam sizes."

TABLE I—SIZES OF ANTHRACITE

Classification	Standard Round Mesh Sizes, Inches Through	Over
Broken	4—7/16	3—7/16
Egg	3—7/16	2—8/16
Stove	2—8/16	1—9/16
Chestnut or (Nut)	1—9/16	11/16
Pea	11/16	8/16
Buckwheat No. 1 or (Buckwheat)	8/16	5/16
Buckwheat No. 2 or (Rice)	5/16	3/16
Buckwheat No. 3 or (Barley)	3/16	3/32
Buckwheat No. 4 or (Bird-eye)	3/32	3/64
Silt (Refuse)	Buckwheat to sludge	
Culm (Refuse)	Pea and Buckwheat to sludge	

When the pea size is grouped with the larger sizes, as is done by the Anthracite Coal Service, the sizes egg, stove, chestnut and pea are called "domestic sizes" and quite recently the development of automatic domestic stokers has popularized the use of No. 1 Buckwheat domestically so that it may now be classed as a domestic size.

Since the domestic sizes are most in demand and

bring the highest prices the object in anthracite mining and preparation is to produce as much of "domestic sizes" and as little of "steam sizes" as possible. The total amount of coal shipped from a mine is called the "yield." In spite of the use of

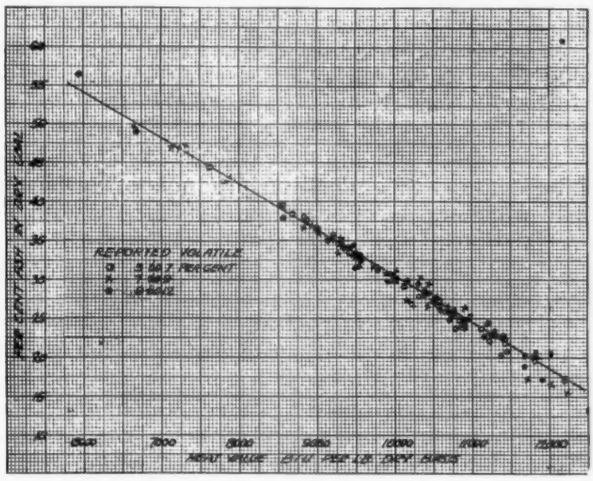


Fig. 2—Relation between ash content and heat value, dry basis of Pennsylvania anthracite silt. Plotted from U. S. Bureau of Mines Analyses as published by Pennsylvania Geologic Survey.

modern equipment and care in handling, the average yield in the Pennsylvania fields runs about 70 per cent pea size and larger, and about 30 per cent of the buckwheat sizes. Besides the yield or shipped product there is a certain amount of fine coal that is discharged from the preparation plant or "breaker" with the breaker water. This refuse coal is called silt and is generally recovered from the water in settling tanks, or large settling basins. Some of this silt unavoidably or through carelessness gets into the streams and becomes the source of "river coal." The annual production of silt amounts to over 10 per cent of the total yield for the whole Pennsylvania anthracite region and has been estimated at 9,000,000 tons. The term "culm" refers to the refuse from an old dry breaker. Because there was little demand for steam sizes at the time the dry preparation process was used most culm banks contained a large percentage of oversize coal and most of them have been reworked to recover these commercial sizes.

Silt As a Steam Plant Fuel

If we assume that within a few years the development of the domestic anthracite stoker will create a domestic market for all the No. 1 Buckwheat produced, then the remaining steam sizes constitute only about 15 to 20 per cent of the yield. It is rather astounding to consider that on this basis the annual production of silt, most of which is considered as waste, would practically equal the yield of marketable steam-size coal. At the present time only about 14 per cent of this silt is being used, and chiefly for the following purposes (a) stoker firing of steam boilers (b) pulverized fuel firing of steam boilers and (c) making fuel briquettes. In connection with (a) and (b) it is used only at or near the mines, but it has been shipped from Pennsylvania to several sections of New Jersey for manufacture into briquettes.

Anthracite silt is much higher in ash content than the domestic sizes, and considerably higher than the steam sizes. Fig. 2 is plotted from the results of numerous analyses made by the U. S. Bureau of Mines and published by the Pennsylvania Geologic Survey. It shows that the ash content of most of the samples analyzed was from 20 to 40 per cent and the corresponding heat value was 11,500 to 8500 B.t.u. per lb., moisture-free basis. Some samples ran as high as 55 per cent ash and some as low as 15 per cent. Silt of higher than 40 per cent ash content is of very little value as a fuel.

The same silt samples for which analyses were published were also screened to determine the per-

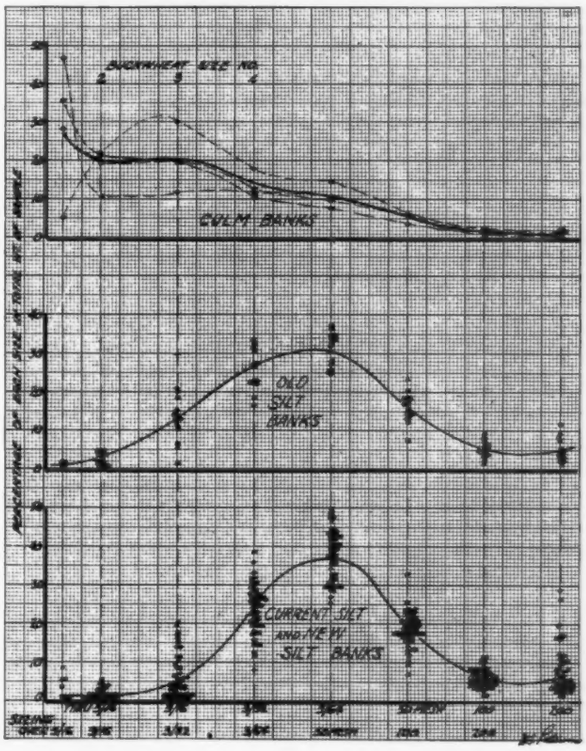


Fig. 3—Curves showing percentages of various commercial sizes and fines in Pennsylvania anthracite culm and silt. Plotted from U. S. Bureau of Mines Screen Tests as published by Pennsylvania Geologic Survey.

centage of various sizes in each sample. The results of these screen tests have been plotted by the author in Fig. 3 and curves are drawn to average the results. The percentage of sizes larger than No. 4 Buckwheat in the culm banks is about 65 while that in the newer silt banks is only about 8 per cent according to the average curve. Fig. 3 also shows a quite noticeable difference between old silt banks and new silt banks.

The relation between ash content and heat value of the No. 4 Buckwheat size screened from the many samples of silt is shown by Fig. 4. In general the ash content of the various sizes of which

the silt is comprised varies inversely as the size. This is illustrated by the fact that practically all of the No. 4 Buckwheat size, as plotted in Fig. 4, has ash content between 12 and 30 per cent and a

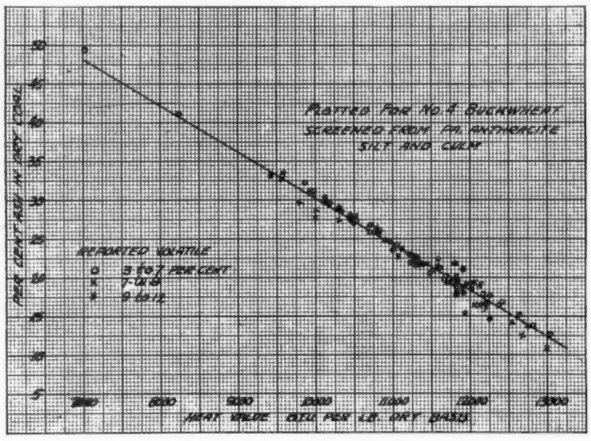


Fig. 4—Relation between ash content and heat value, dry basis, of No. 4 Buckwheat screened from Pennsylvania anthracite silt and culm. Plotted from U. S. Bureau of Mines Analyses as published by Pennsylvania Geologic Survey.

heat value between 13,000 and 10,000 B.t.u. per lb., moisture-free basis.

The volatile content of the various samples analyzed is indicated on Figs. 2 and 4. It is peculiar that, whereas the volatile content of the commercial sizes of Pennsylvania anthracite seldom exceeds 5 per cent, the volatile content reported for some of the silt was over 10 per cent. According to the published report of these analyses, this is attributable to the presence of water of hydration in the ash-forming minerals of the sample and does not represent the percentage of combustible volatile matter. The volatile content of silt from the Northern Pennsylvania field is in general higher than that from the other Pennsylvania fields.

Air Requirements and Products of Combustion

In the author's article in the February issue of this magazine a method was described and a chart presented for the graphical determination of air requirements and combustion products of all U. S. coals having more than about 7 per cent volatile content, dry basis. It was pointed out that the air requirements per pound of fuel for coals having less than 7 per cent volatile content are considerably greater and cannot therefore be averaged with the requirements for the other higher volatile coals without affecting the accuracy of the result. The reference to anthracite in that article as any coal having less than 7 per cent volatile content therefore included also super-anthracite which has a much higher carbon/hydrogen ratio than ordinary anthracite and has consequently been treated separately in the present discussion. The anthracite curves of Fig. 1 and Fig. 6 of the previous article were plotted from a group of analyses of the better quality anthracites and super-anthracite and are therefore not truly representative of either rank considered separately.

Fig. 5 shows a comparison of the air requirements of these two ranks of anthracite plotted against the dry heat value of the fuel and for the same CO_2 content in the products of combustion. Because of the difference in these requirements and because super-anthracite is not used to any extent for steaming purposes the working chart plotted for variable CO_2 and variable carbon loss, Fig. 6, was drawn for ordinary anthracite only.

The combustion engineer interested in the air requirements and combustion products of anthracite will in general have occasion to deal only with the combustion of the small commercial sizes and the waste products such as silt and river coal. As mentioned previously these sizes are burned principally on forced-draft chain grate stokers, and, to a limited extent, silt and river coal are burned in pulverized form at or very near the source of supply. Certain combustion losses which affect the air requirements are inherent with each method of burning, the most important of which is unburned carbon. In connection with stoker firing, this results from (a) fine coal sifting through the grate, (b) fine coal and partly burned coal blown from the grate and carried into the boiler and stack and (c) the unburned carbon carried over the end

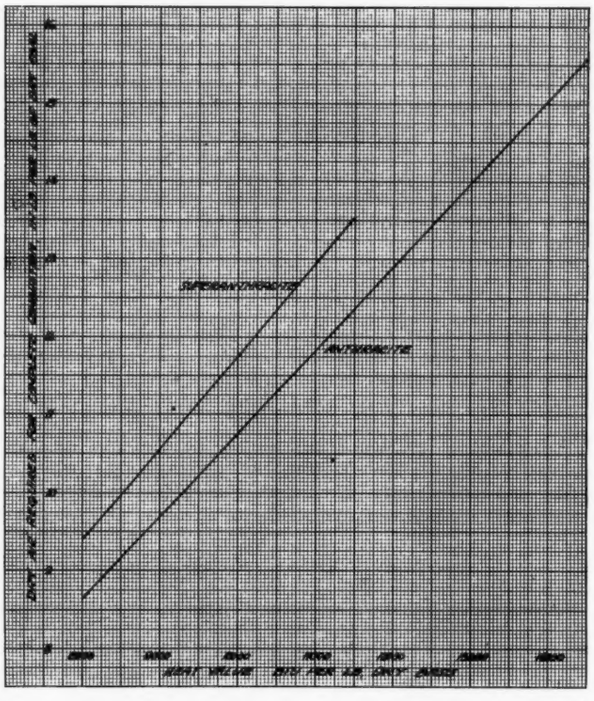


Fig. 5—Comparison of average air requirements of anthracite and super-anthracite based upon complete combustion of dry fuel with dry air to produce 14 per cent CO_2 in combustion products.

of the grate with the ash. The amount of the "siftings" loss depends primarily on the design of the grate and sizing of the coal. The amount of the other losses depends primarily on the combustion rate, furnace design and sizing of the coal. In

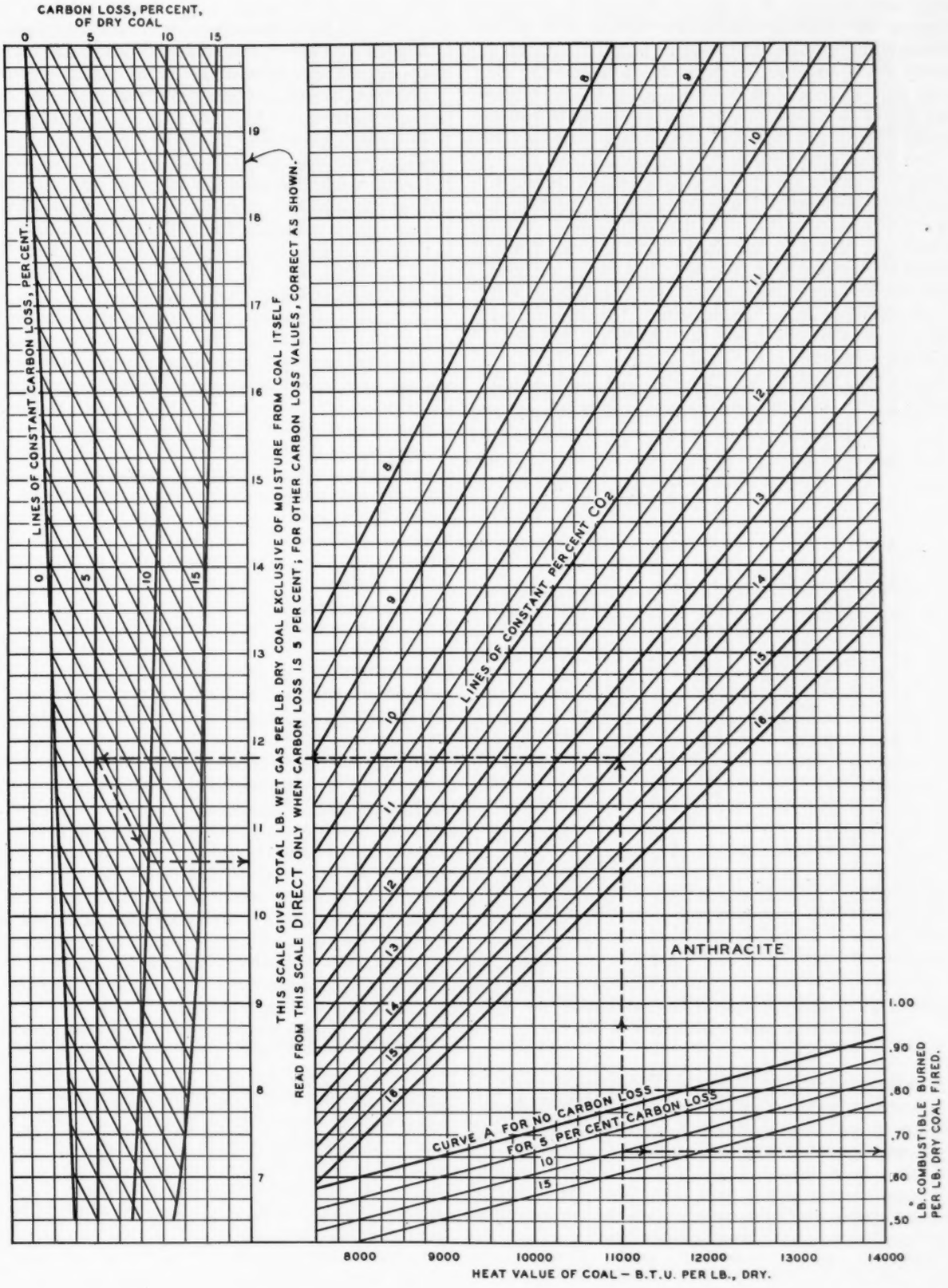

CARBON LOSS, PERCENT, OF DRY COAL
0
5
10
15
LINES OF CONSTANT CARBON LOSS, PERCENT.
THIS SCALE GIVES TOTAL LB. WET GAS PER LB. DRY COAL EXCLUSIVE OF MOISTURE FROM COAL ITSELF
READ FROM THIS SCALE DIRECT ONLY WHEN CARBON LOSS IS 5 PER CENT; FOR OTHER CARBON LOSS VALUES, CORRECT AS SHOWN.
LINES OF CONSTANT, PER CENT CO_2
ANTHRACITE
CURVE A FOR NO CARBON LOSS
FOR 5 PER CENT CARBON LOSS
LB. COMBUSTIBLE BURNED PER LB. DRY COAL FIRED.
HEAT VALUE OF COAL – B.T.U. PER LB., DRY.

Fig. 6—Chart for determination of air requirements and combustion products of all U. S. anthracite coal. (Exclusive of super-anthracite or graphitic coal)

large installations it is good practice to provide hoppers or settling chambers below the boiler passes where convenient, and to pipe the recovered "carry over" back to the grate to minimize the loss from this source. In connection with pulverized fuel firing of anthracite the carbon loss is caused by the burning particles of coal being extinguished before they have completely burned, either by entering the boiler or falling to the ashpit. Obviously therefore, fineness of pulverization and burner design are important factors in the control of this unburned carbon. To allow for the maximum probable variation in carbon loss with different methods of firing the Fig. 6 chart is provided with a correction scale for from zero to 15 per cent loss. Figures read direct from the chart are automatically corrected for 5 per cent loss.

The other combustion loss in connection with stoker firing with which we are concerned is due

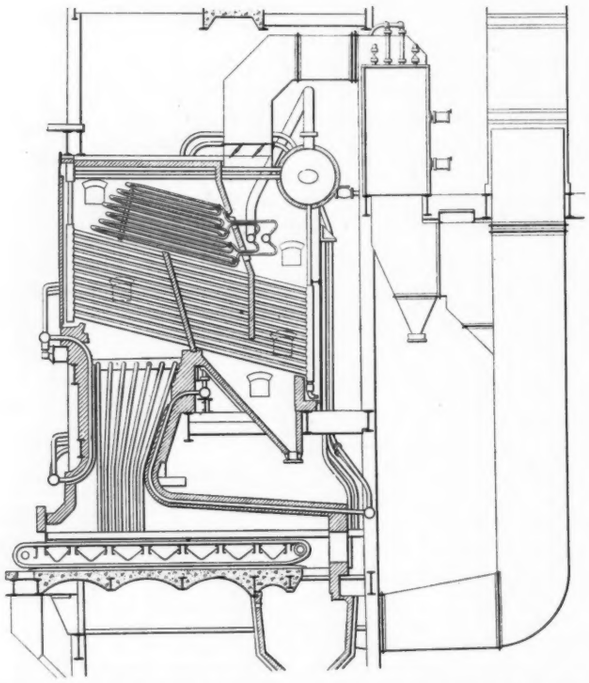


Fig. 7—Typical traveling grate stoker arrangement for small commercial sizes of anthracite or silt.

to the incomplete combustion of carbon to carbon monoxide, or the reduction of carbon dioxide to carbon monoxide. This loss is indicated by the presence of carbon monoxide in the flue gases and can only be eliminated by proper furnace design and careful regulation of air supply. In modern well designed units all traces of carbon monoxide can be eliminated by proper operation.

Use of the Figure 6 Calculation Chart

The use of the working chart for any grade or size of anthracite, exclusive of super-anthracite, requires a knowledge of the heat value, CO_2 at point in system for which gas weight is to be calculated, the carbon loss, and the moisture content of the coal. The chart is based on complete combustion of the carbon burned. Since there is a very definite relation between ash content and heat value, as indicated by Figs. 1, 2, and 4, the heat value may be quite accurately determined from the ash content.

The total weight of gas resulting from the commercial burning of one pound of coal with atmospheric air consists of (1) the dry products of combustion resulting from combustion of that part of the coal which is actually burned, including the excess oxygen and nitrogen in the excess air, (2) the moisture resulting from the combustion of the hydrogen in the coal, (3) the moisture of the coal itself, as fired, and (4) the moisture due to humidity of the air used for combustion.

The gas weight read from the chart, with proper correction for carbon loss by the scale provided, is the total wet gas weight exclusive of item (3) above. This item may be appreciable or negligible depending on the sizing of the coal, method of storage, or weather conditions. If known it may be expressed as lb. moisture per lb. of dry coal and added direct to the reading from the chart. If unknown and neglected, the error introduced will generally be less than one per cent. The allowance made in the chart for moisture in the atmospheric air corresponds to 50 per cent relative humidity at 70 deg. fahr.

For a discussion of the reasons why the moisture free basis is used, why lines of constant CO_2 are used instead of constant excess air, and for detailed instructions as to the use of the chart and the method of calculating the unburned carbon loss, the reader is referred to the author's previous article.

The air weight supplied per lb. of dry coal plus the weight of combustible burned per lb. of dry coal equals the combustion products per lb. of dry coal exclusive of the moisture from the coal. The combustible burned equals the total weight of combustible per lb. of coal minus the carbon loss. It therefore equals (1-ash-carbon loss) and the air weight per lb. of dry coal may be calculated from the chart by subtracting the quantity in parentheses from the gas weight read from the chart. Curve A of Fig. 6 gives the amount to be subtracted for various values of carbon loss.

Numerical Example of Use of Figure 6 Chart

Assume anthracite coal of 25 per cent ash, dry basis, and about 10 per cent moisture, as fired. From Figs. 1, 2 and 4 the heat value will be very nearly 11,000 B.t.u. per lb. regardless of whether the coal is waste fuel or commercial size; or if the heat value is known so much the better. Assume also a total carbon loss of 10 per cent or .10 lb. per lb. of dry coal fired, and that the coal can be burned with excess air corresponding to 14 per cent CO_2 in the furnace without producing any CO. The calculation is then as follows to determine the total gas weight; enter chart on abscissa scale at 11,000 B.t.u. heat value, proceed vertically upward to the 14 per cent CO_2 line and thence to the left horizontally to the ordinate scale. The value if read direct from this scale is the weight of gas per lb.

of dry coal for 5 per cent carbon loss exclusive of the moisture from the coal itself. Since our calculations are to be based on 10 per cent unburned carbon we proceed to the left to the 5 per cent carbon loss line and then correct for 10 per cent carbon loss by moving diagonally downward along or parallel to the 60 deg. guide lines to the 10 per cent carbon loss line. Reading the results directly opposite on the ordinate scale we obtain 10.60 lb. gas per lb. dry coal. The moisture, as fired, is .10 lb. or .10 ÷ .90 = .111 lb. dry basis. So the total weight of wet gas per lb. of dry coal becomes 10.60 + .11 = 10.71.

The air required then equals 10.60 lb. minus the combustible burned which may be obtained direct from Curve A for 10 per cent carbon loss. The air required to produce 14 per cent CO_2 in the products of combustion is therefore 10.60 — .66 = 9.94 lb. per lb. of dry coal.

For heat balance calculations requiring segregation of dry gas weight, the average hydrogen content may be obtained from Fig. 1 and used to calculate the weight of moisture in the flue gas from this source.

REFERENCES

Fuels, Past and Prospective, S. W. Parr, *Transactions ASME*, vol. 50, no. 8 (1928).

American Fuel Resources, O. P. Hood, *Transactions ASME*, vol. 50, no. 8 (1928).

Constitution and Classification of Coals, A. C. Fieldner, *Transactions ASME*, vol. 53, no. 33 (1928).

Burning Characteristics of Different Fuels, H. Kreisinger and B. J. Cross, *Transactions ASME*, vol. 53, no. 33 (1928).

Progress in Fuel Utilization in 1929, ASME Fuels Division, *Transactions* ASME, vol. 52, no. 1 (1930).

The Preparation of Anthracite, T. M. Chance, *Transactions ASME*, vol. 52, no. 1 (1930).

Economics of Reclamation of Anthracite Silt Coal and Culm, H. H. Dechant, *Transactions ASME*, vol. 52, no. 1.

Economic Status of Anthracite and Factors Effecting Its Use as a Domestic Heating Fuel, A. F. Duember, *Transactions ASME*, vol. 52, no. 1.

Anthracite Culm and Silt, Sisler, Fraser and Ashmead, Pa. Geologic Survey Bulletin M 12 (1928).

Analyses of Coals, U. S. Bureau of Mines, Bulletin 22.

●

Fifth Annual Midwest Bituminous Coal Conference

The Fifth Annual Midwest Bituminous Coal Conference will be held at Purdue University, Lafayette, Indiana, on April 14-15. This educational conference is sponsored by Purdue University and University of Illinois in cooperation with the Coal Trade Association of Indiana, Illinois Coal Bureau, Illinois State Geological Survey, Fuel Division of the A. S. M. E., and the Indiana Branch of the American Association of Power Engineers. Four sessions are planned, covering industrial research, retail coal dealers and semi-industrial applications to Midwest coals. Inquiries concerning this conference may be addressed to W. A. Knapp, Engineering Extension Department, Purdue University, Lafayette, Indiana.

Data on Municipally-Operated Electric Light and Power Plants

"What 100 representative Cities Pay for Electric Light and Power under Municipal Ownership," is the title of a 56-page pamphlet, compiled by C. F. Lambert. This gives the light and power rates, valuation of property, operating expenses, earnings and other conditions pertaining to one hundred municipally-owned light and power plants. Many of these 100 cities are competing with private companies. Some are tax free. These comparisons are interesting to those cities which now operate their light plants as well as those cities which are attempting to secure an equitable adjustment of their rates, or those contemplating public ownership. A table is also included showing charges for services in twenty representative Canadian Municipalities. This booklet may be obtained direct from the publishers, Burns & McDonnell Engineering Co., consulting engineers, 406 Interstate Building, Kansas City, Mo. Price, $1.00.

●

Dunbar Engineering Co., representing the Edward Valve & Mfg. Co., East Chicago, Indiana, removed its office from 122 East 42nd Street to 21 West Street, New York City.

●

Air Preheater Corporation, Wellsville, N. Y., announces the appointment as its representative in St. Paul, Minnesota, territory, of the Fuel Economy Engineering Company of that city.

●

American Smoke & Soot Washer Co., Inc., 1775 Broadway, New York, Charles M. Gerhold, president, announces the appointment of G. O. French as New York District Sales Manager. Mr. French since 1927 has been New York District Sales Manager for the Air Preheater Corporation.

●

Duluth, Minn., Central Heating Station Started

The latter part of February, ground was broken at Duluth, Minn., and work started on the new central heating station of the Duluth Steam Corporation.

The plant will comprise four boilers, each of 6,000 sq. ft. heating surface, designed for 450 lb. per sq. in. The plant, however, is expected to operate at 150 lb. Each boiler will be equipped with a 5-ton unit pulverizer and tubular air-preheater, also fly-ash and cinder eliminators. A small house turbine-generator will supply power for auxiliaries.

The plant is expected to start operation in September of this year, supplying steam at 150 lb. to the business district and for certain industrial and process purposes.

Past and Present Developments of Water Gages

By G. E. SAMS
The Reliance Gauge Column Co.
Cleveland

The author briefly reviews the history of water gages as applied to steam boilers and touches upon the high points of their development up to the present. The effects on gage glasses of peculiar properties of feedwater and of high pressures and temperatures are discussed at some length. The use of mica either as protection for the glass or as a substitute for it is indicated as a solution both to the problems incident to troublesome feedwater and to high pressures.

A HISTORY of boilers would begin 150 years B. C. with the experiments of Hero of Alexandria. Historians tell us that he conducted experiments with ornamental copper pots to generate steam enough to revolve a light ball. It is not probable that he had or needed a water level indicator.

In fact, from the few vague mechanical descriptions made by historians, of those who followed Hero in steam experiments, we do not find any record of a level indicator until about the year 1700. At that time, Thomas Savery, an inventor of London, exhibited a boiler in connection with an engine for pumping water. This, we believe, was one of the first commercial boilers. The method Mr. Savery employed to determine the water level is best described by himself, a record of which was found in a published pamphlet he had written.

"If you would at any time know if the great boiler be more than half exhausted, turn the small cock, whose pipe will deliver water if the water be above the level of its bottom, which is half way down the boiler, if not, it will deliver steam. By which means, nothing but a stupid and wilful neglect or mischievous design carried on some hours can anyways hurt the boiler, and if a master be suspicious of a servant to do mischief, it is easily discovered by these gage pipes. If he comes when the engine is working and on turning the cock sees steam, then such a servant needs punishment."

From this description and the engraving shown in Fig. 1, it is clear that gage cocks preceded any visible type of level indicator. Other engravings of boilers built from 1700 to 1800 are evidence that this means of indication was the most popular during that period.

Another device which was used during that time is illustrated in Fig. 2. This was simply a float on the inside of the boiler connected to a steel rod which passed through a stuffing box, the rod attached to a chain passing over a pulley, with a marker on the end. The position of the marker indicated the water level. Obviously this could be used only with a very low steam pressure, as very little friction in the stuffing box would overcome the buoyancy of the float.

As nearly as we can determine, the familiar tubular glass type of sight gage came into use sometime after 1800. Its inventor we find no record of, but he gave to boilers a device which has lasted to the present day. The valves employed to hold the glass have been many and varied in design. At the beginning they were little more than pet cocks, but the principle of a glass tube has survived. A modern design of this gage is shown in Fig. 3.

The next innovation we find in 1862, when a boiler was made and fitted with a glass-covered slot for observing the water level. This probably was the first usage of what we know as a bull's eye, which has been employed extensively on test boilers.

Many years later when steam pressures had advanced to about 200 lb., a German inventor designed what is known as the reflex type of gage. The principle of this is reflecting light rays on V shaped grooves. A section through a modern design of reflex gage is shown in Fig. 5. In practice, light entering through the front of the glass is reflected back out again where the grooves remain open, giving a silvery appearance. Where water fills the grooves, the light rays are not reflected and that portion looks black.

Up until a very few years ago, the tubular glass gage and the reflex type gage were the only commonly-used water level indicators. They were sufficient for low pressures. As steam pressures were increased, it became necessary to produce

glass which would withstand the increased temperatures. This has been accomplished to a remarkable degree, but glass has its limitations. The nature of its process of manufacture imposes char-

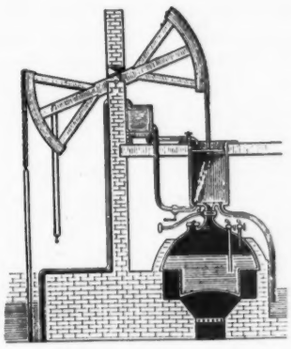


Fig. 1

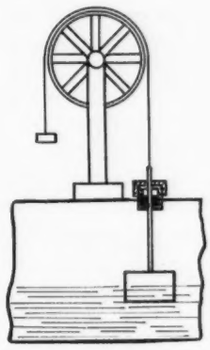


Fig. 2

acteristics which limit its usefulness. It is well known that all glass has internal strains. An attempt to control them by heat treatment has been only partially successful, because it is exceedingly difficult to determine just why and where the strains are. Polarized light is used to do this but this does not guarantee accuracy. Being extremely brittle, the action of alternate high and low temperatures upon these strains ultimately causes breakage.

Another serious handicap is corrosion. Glass will dissolve or eat away. Although we know of very little data recorded on this subject, it is common knowledge that the higher the temperature, the faster the corrosion. Our experience has been that certain chemicals in boiler waters accelerate the corrosion.

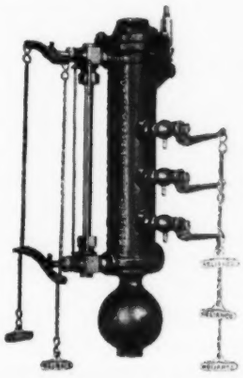


Fig. 3—Modern design of tubular glass gage.

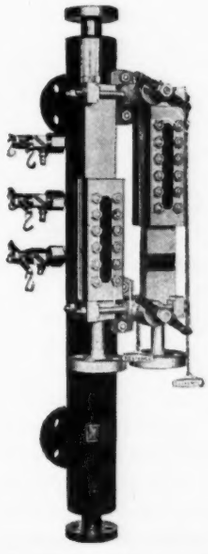


Fig. 4—Glass window gage for 1500 lb. operating pressure.

Because of these two serious difficulties and the varied conditions under which they might arise, it is difficult to recommend a steam pressure where the use of a tubular glass should end and something else begin. As a general rule, however, a tubular glass of good manufacture should give satisfactory results up to 250 lb. pressure. The term "satisfactory" is general. We have run across several plants where tubular glasses were used to 400 lb. or more, but these are exceptions, and it was found that glasses had to be changed comparatively often. Care must be used to insure proper installation. The fittings must be in alignment and the packing glands must be pulled up with nearly equal pressure. Glasses which are not straight or have other flaws should be rejected.

Likewise the usual practice from 250 to 450 lb. has been the prismatic type of glass. In general, this has proved fairly satisfactory. Some difficulty has been experienced at the higher pressures with corrosion of the glass and warping of the housings. In a housing for a prismatic glass, this warping can not exceed the take-up of the asbestos gasket and cushion, which is very little, or the glass will break. If a housing has been warped, the only

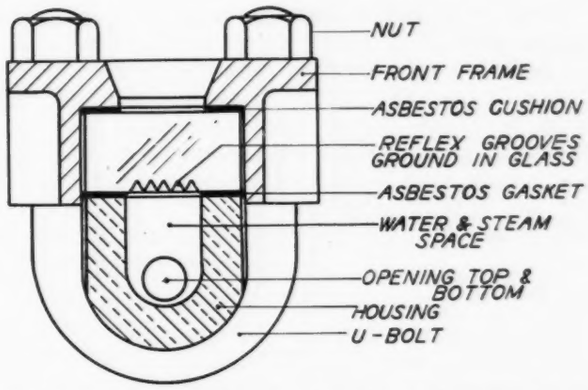


Fig. 5—Section through modern design of reflex water gage.

remedy is to remachine the glass seat to a plane surface.

In some plants there has been complaint that the prismatic glasses dissolved rapidly. Apparently, the corners of the prisms were attacked more quickly than the flat surface. These cases, however, usually occur with unusual water conditions or high temperatures.

When steam pressures were advanced above 500 lb., it was found necessary to protect the glass. In general, the dissolving of the glass was so rapid that it had very short life unless protected. The practice has been to insulate it from the steam and water by a sheet of mica. To accomplish this, a new design of gage was required. Housings had to be of heavier construction to withstand the pressure and, just as important, to retard warping. One of the most familiar designs of flat-glass, mica-protected gages is shown in Fig. 6. It is necessary to make it double-sided to admit illumination from the rear. It will be seen that the gasket is first placed on the seat followed by a sheet of mica. The glass is placed on the mica and then a cushion on the glass. In this way, the glass is separated from the steam and water and the outer clamp does not touch the glass. When assembled, the glass carries

both the clamping load and the steam pressure. This design of gage has been made both here and abroad, with installations as high as 1300 lb. with which there have been many varied operating experiences.

It was early realized that a gage of this type had to be nicely made. The glass seat in the body must be rough machined to remove metal strains, finish cut and lapped to within .002 in. of a plane surface. The glasses used must be parallel and present a plane surface to about the same tolerance. Many other refinements were found necessary, and last but not least, more than ordinary care must be exercised in assembly. This last item has been one of the causes of trouble in the field. In order to make a perfect assembly, it is necessary that each nut be pulled up very much the same as every other nut, to equalize the clamping strain. The average workman does not realize the importance of this, and in order that it be done properly where these gages are installed, one man in a plant should be properly instructed and appointed to do the work.

The glasses used in this type gage must be of the highest quality to resist temperature changes. It has been the procedure of manufacturers of these glasses to heat-treat them in such a manner that when breakage occurs the fragments interlock, preventing their flying from the housing. In doing this, a long step toward safety was made. However, an equally dangerous item still remains. It is necessary that a plain asbestos gasket be used to

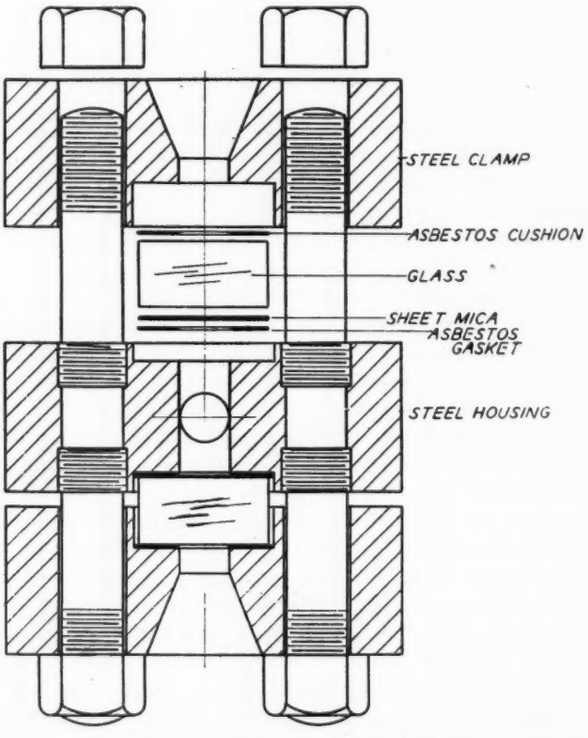


Fig. 6—Flat glass mica protected gage for high pressure service.

cushion the glass. Invariably, when a glass breaks, the gasket blows out. Many times the gasket blows without the glass breaking. In either case, there naturally is a jet of steam which must be stopped.

It will be noted from the foregoing that many difficulties were encountered where glass was used

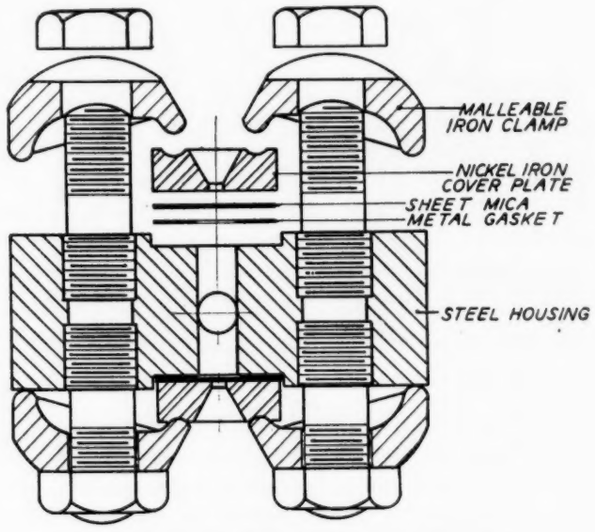


Fig. 7—Section through mica window gage.

with high pressures and temperatures, but boiler pressures were steadily increased. Some sort of water gage had to be designed that would withstand them. Having proved itself ample protection for glass, mica was resorted to.

Mica had proved itself immune to temperatures. Flexibility is a natural characteristic; therefore, warpage of its housing had no ill effects. Its capability to withstand pressure is amazing when held so that a narrow slot is exposed. As an example, when clamped in a housing having an opening ¼ in. x 12½ in. long, a sheet of mica .007 in. thick will withstand 1000 lb. pressure per sq. in. In the same housing, a sheet .012 in. thick will withstand 2000 lb. pressure. These and many other figures were verified, many times over. Further proof of its flexibility was found during pressure tests when each sheet, before rupturing, actually bulged from 1/64 to 1/32 in. By this, we mean the mica stretched or distorted the same as a rubber diaphragm would. When the mica ruptures, it does not rip the full length of the slot, but breaks through in one point. The size of the break may be anywhere from a pin hole to ½ in. long, rarely more. A section through a mica window gage is shown in Fig. 7. A number of these gages are now in service, some at 1700 lb. steam pressure, and they are proving very satisfactory.

A typical high pressure installation of such a gage is shown in Fig. 8. It is installed on a 1400-lb. pressure Connelly boiler at Station B of the San Antonio Public Service Company, San Antonio, Texas. This gage has been giving very satisfactory service for over a year.

The advantages of mica over glass is illustrated somewhat differently in an installation at the Court Street Plant of The Consumers Power Company, Flint, Michigan. Here the pressure is compara-

tively low, around 200 lb., but the chemical condition of the boiler water dissolved tubular glasses in less than a week. Since mica window gages were installed the only maintenance is cleaning once in four or five months.

In order to see the water level clearly in any double window glass or mica gage, it is necessary that it be properly illuminated. By this, we mean not simply an electric lamp of high wattage placed behind it, but a lamp enclosed in a housing with a good reflector to throw its light directly into the slot and nowhere else. The light should be of even intensity over the entire slot and preferably sent from below so that the meniscus of the water level will be reflected as a twinkling star.

In locations where there is an abundance of natural light or where other electric lamps are in front of a water gage, it will be found that by shielding the gage the water level will appear much clearer. This shielding must be done according to local conditions, but where possible a sheet-iron box extending from the front, as long as

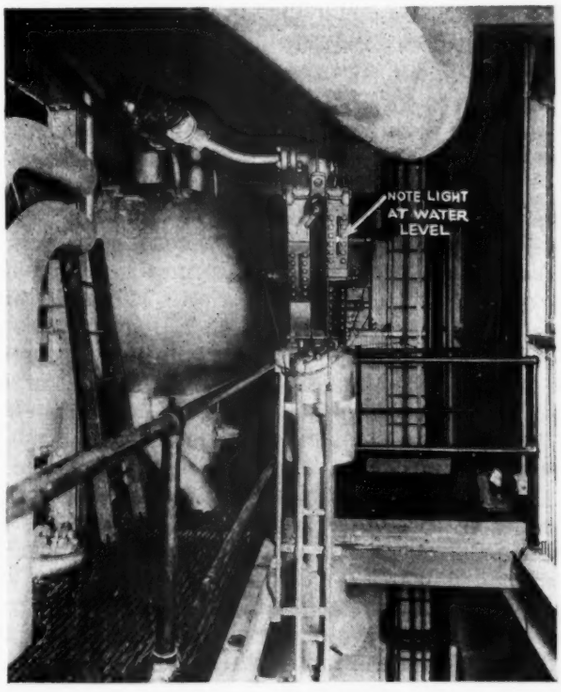


Fig. 8—Typical installation of high pressure, mica window gage.

necessary or conditions permit, is recommended. This gives the effect of looking into a dark well in which the water level stands out very clearly.

Another means of viewing the gage on very high boilers is by periscopes. Care must be exercised to use only perfect mirrors and set them at exact 45 deg. angles, otherwise, false water levels may be seen. Periscopes, however, require a straight run to floor level and not all boiler rooms have clearance for them.

This narrative on water gages would not be quite complete without a few words on the difference in appearance of a water level of a high pressure boiler and a low pressure boiler. True, they both use water, but low pressure boilers show a comparatively still and cool column of water, whereas the high pressure boiler level constantly moves due to increased condensation dripping upon it. Also, all mica is slightly tinted and whether used as a glass protector or as a window by itself the shaded appearance remains. This along with the difference in height from floor level, usually creates the different appearance. This is sometimes confusing to the engineer and fireman, who, being accustomed to seeing an actual column of water from any position they may be in, find it necessary to look at a gage from one direction only, and see a bright line or spot fluttering in the slot. The safety of the boiler and perhaps their lives, depend on the level of the water in the boiler and it is only natural for the operator to want to be positive of the accuracy of his reading. Manufacturers of water gages are fully aware of this and are doing everything possible to build gages which are absolutely safe and reliable, but the change of appearance is something beyond control and operators will have to adjust themselves to it.

•

Sir Henry Fowler Inaugurated President of the Institute of Metals, London.

At The Institute of Metals Twenty-fourth Annual Meeting held in London, March 9 and 10, the retiring president, Dr. Richard Seligman, inducted the incoming president, Sir Henry Fowler, K.B.E., LL.D., D.Sc., into the Chair. The new president was born in 1871 and was educated at Evesham and Mason Science College (now the University of Birmingham). Starting with an apprenticeship at the Locomotive Works of the Lancashire & Yorkshire Railway at Horwich, he has become prominently identified in positions of increasing responsibility in the various fields of railroad engineering. He has been president of many engineering associations, among them the British Association for the Advancement of Science, the Institution of Mechanical Engineers, etc., etc.

•

A report from the Associated Gas & Electric System states that 179 new industrial concerns have established plants in areas served by the system in 1931. These concerns will employ 6814 workers, and have contracted for 11,367 horse power of electricity and 25,246,000 cubic feet of gas. 205 concerns in the areas increased their activities in 1931, with additional contracts for 11,615 horse power and 69,258,000 cubic feet of gas. The principal areas served by the company are in New York, Pennsylvania, New Jersey and Massachusetts.

History and Developments in the Art of Welding Ferrous Metals

PART III

By A. J. MOSES
Hedges-Walsh-Weidner Co.
Chattanooga, Tenn.

Part III of Mr. Moses' series continues the discussion of fusion welding processes taking up first the acetylene process, the history and development of which are narrated, and its manifold uses commented upon. Electric arc welding is then considered under its two main divisions, i.e., carbon arc welding and metallic arc welding. Part IV, to be published in the next issue, will take up the application of fusion welding for pressure vessels as recently sanctioned by the A.S.M.E. code and will conclude the series.

Acetylene welding is the most important of the fusion methods employing the hot flame obtained by the combustion of gases. Acetylene is the nearest approach to gaseous carbon, containing more than 92 per cent of that element. Its combustion with pure oxygen produces a maximum flame temperature of about 6300 deg. fahr. This temperature is considerably higher than that obtained by oxy-hydrogen combustion. In welding this flame is produced and controlled by a torch in which the gases are mixed and emitted through a small orifice known as the welding tip. The gases are fed to the torch through hose from storage cylinders or gas generators. The ignited gas mixture at the welding nozzle produces a conical flame consisting of an inner and outer cone. The maximum temperature is attained at the tip of the inner cone. The color and relative size of the two cones are dependent upon the ratio of the gases in the mixture. Oxidizing, reducing and neutral flames are distinctive and readily obtained by gas control valves in the handle of the torch. For welding, a neutral or slightly reducing flame is desirable.

When the oxy-acetylene flame is played upon a piece of metal, it causes a rather rapid fusion within a small area in close proximity to the tip of the inner cone. The tip of this cone should be held slightly above the surface to be fused. In the welding of light gage sheets, the edges are often flanged before abutting eliminating the necessity of using the welding rod. The flame is directed upon one end of the juncture fusing the two edges into a pool of liquid metal. By a rotating and forward movement of the welding tip, this pool is caused to form progressively along the joint thus closing the seam. The size of the welding tip used depends upon the thickness of the material. It should be no larger than is sufficient to procure thorough fusion through the joint depth. In welding heavy sections more than $\frac{3}{16}$ in. thick, the abutted edges are beveled forming a groove. Where the metal is 1½ in. or more in thickness, the edges are usually preheated by gas or oil torches. Preheating is also necessary when welding brittle materials like cast iron or cast aluminum with welding rods of the same composition. When welding these materials with special rods, such as bronze rod in the case of cast iron, or an aluminum alloy rod containing a small amount of silicon in the case of cast aluminum, local preheating is sufficient, and sometimes even this can be eliminated. The purposes of preheating are economy, speed in welding and a reduction of shrinkage stresses. A filler material in the form of a welding rod is required in filling in a grooved joint. This rod is fed into the center of the pool of molten metal, the end being continuously melted by the heat of the flame.

Hot flame welding as now practiced had its inception in the invention of the oxy-hydrogen blowpipe by Dr. Robert Hare of Philadelphia in the early part of the last century. The oxy-hydrogen or air-hydrogen flame was used in lead burning and in gold and platinum welding. It remained a laboratory instrument until industrial oxygen and hydrogen were made available by the electrolysis of water about the year 1880. Since that time acetylene has superseded hydrogen in most industrial processes. Acetylene was discovered in 1837 by Davy. But calcium carbide, the source of acetylene, was not cheaply available for more than a half century after Davy's discovery of this gas. The method of producing calcium carbide in the electric furnace was accidentally discovered in 1892 at the plant of the Willson Aluminum Co. in North Carolina. The process was rapidly commercialized, acetylene being in demand for illuminating purposes. De-

spite its explosive properties rapid development of acetylene welding followed. This application attained the greatest head-way in France. About 1900, the late Edmond Fouche brought out the first practical oxy-acetylene welding torch. In 1897, the Belgian chemists Claude and Hesse received patents on the acetone absorption method of storing acetylene in cylinders, which method greatly reduced the hazards of handling this dangerous gas. From 1905, the commercial application of this welding process has spread rapidly. Up until the last decade, it was the most reliable fusion method available in making general repairs and in many manufacturing processes.

In many plants, acetylene is piped from a central generating station throughout the factory as is also oxygen which is conveyed through a separate piping system from a central cylinder manifold. Portable welding and cutting outfits are also available using oxygen and acetylene stored under pressure in portable cylinders. Such outfits can be carried to out of the way places for repair jobs. Most of these jobs are small and the work can be done more cheaply and quickly by the acetylene process than any other with exception under certain conditions of the electric arc method to be discussed later. Where cylinder acetylene is to be used, the cost of a portable acetylene welding outfit is very small consisting of rubber hose, pressure regulators and a welding torch. An arc welding outfit is more expensive but the power consumed in the electric process is much cheaper than the gases used in gas welding. In those cases where the cutting of metal is necessary in conjunction with the welding operation, the gas process is frequently given preference over the electric. But the tendency now in jobs of any size, is to provide equipment for both methods. As regards the position in which the weld is to be made, acetylene welds can be made in horizontal, vertical and overhead positions, but welds made in vertical and overhead positions require more time and entail greater consumption of materials the amount of each depending upon the skill of the operator. All of the above discussion refers to that class of work where time, economy and facility are deemed of more importance than the attainment of a joint of maximum efficiency. Only too often, however, are many important jobs placed in this category.

For joining thin gage plates of steel and other metals, the acetylene process enjoys a distinct advantage over the electric arc. In fact the arc welding of plate $\frac{1}{16}$ in. thick and under, is extremely difficult if not impossible. With gas welding on the other hand, the necessity of preheating heavy steel sections, limits its application in this field. In isolated cases this preheating operation may be justifiable, but as a continual production proposition, it constitutes a burden too heavy to be borne. This method has a wider scope than those previously discussed in that it is applicable to most of the metals and alloys. Among these are, mild and low carbon steels, cast iron, malleable iron, nickel, copper and aluminum and most of the alloys of these metals. This method takes precedence over all others in the welding of cast iron and aluminum.

The skill of the operator and the nature of the welding rod used are factors of first importance in obtaining good oxy-acetylene welds. Sustained efficiency is heavily taxed under such fatiguing conditions as attend the welding of preheated heavy sections. However, under proper conditions including in some cases subsequent annealing, sound, low-carbon steel welds can be produced which in tensile strength are equivalent to the plate material. The ductility of such joints is shown by an elongation of 15 to 20 per cent in 2 in. as against an elongation of 30 to 40 per cent for the base material. It is not difficult to eliminate porosity in the acetylene welding of this material. The most common defects are laps, cold-shuts and oxidized metal. The causes of these are: the overflowing of the hot pool of metal over the cold without proper fusion of the latter; the too rapid addition of filler material; the dropping of filler material on to cold metal instead of into the welding pool; the insufficient preheating in the case of heavy section welds; and improper regulation of the flame permitting an excess of oxygen. Most of these defects are discoverable only by tests to destruction and microscopic examination. Such non-destructive tests as x-ray examination cannot be relied on as a common denominator in evaluating welds as related to test samples. This makes it necessary that the technique of the operator be most carefully ob-

Steam mains in 40 story office building oxy-acetylene welded in position.

served throughout the entire procedure. This applies whether the operation be manual or semi-automatic. Surface defects and other discoverable ones can be repaired by this same method of welding.

Many pressure vessels have been fabricated by this method. Because of the many difficulties at-

Oxy-acetylene welding high pressure steam header.

tending the welding of heavy sections, this application has generally been confined to plate thicknesses under 1¼ in. Metal deposited by the acetylene process is essentially cast material of such a nature that in the unannealed state, it is not sufficiently ductile to withstand the locked up stresses encountered in heavy plate work. Oxy-acetylene is most advantageously used in the cutting of metals, the welding of light gage plates, cast iron and some of the non-ferrous metals such as copper and aluminum. This process was developed to a higher degree of perfection earlier than its greatest competitor, electric arc welding. But during the past few years the latter art has outstripped it in many fields.

Electric arc welding is divided into two main divisions which are carbon arc welding and metallic are welding. In the carbon arc process, the heat required is produced by striking and maintaining an electric arc between a carbon pencil and the work material which constitutes the other electrode. The carbon method is very similar to the oxy-acetylene in that the parts to be joined are fused together in an advancing pool of liquid metal. When necessary, additional filler material in the form of weld rods of strips are fed into this pool. The preparation of the work is practically the same. Due to the high temperature of the arc, preheating the work is ordinarily unnecessary. In welding brittle materials it must be done in order to relieve shrinkage stresses. Direct current is best for carbon arc welding. The currents used vary from 100 to 600 amperes, and the arc voltages from 60 to 100 volts. Are lengths vary from ¼ to 1½ in., depending upon the currents used. The use of direct current, a long arc, and positive polarity for the work material, tend to prevent carbonization of the weld metal, a common fault of carbon arc welding.

In the metallic arc process, the filler material or weld rod is made one of the electrodes, and the work material, the other. The operation is much simpler than that of the carbon arc in that filler material is automatically added from the consumption of the metallic weld rod. Immediately an arc is established between a point on the work material and the electrode, the metal at those points is raised beyond the fusing temperature. The electrode end melts and drips, or is projected in a liquid or gaseous form, across the arc into the fused pool or crater within the joint. After striking an arc, the electrode is fed into and along the weld joint at a rate practically equal to that of the rod consumption. This produces a thin layer or bead of deposited metal along the juncture. In welding thin plate, less than ¼ in. in thickness, one such layer is sufficient because the arc crater penetrates to a depth equal to such thickness. Heavier plate is beveled or grooved at the seam. The weld is built up from the bottom of this groove with successive layers of deposited metal.

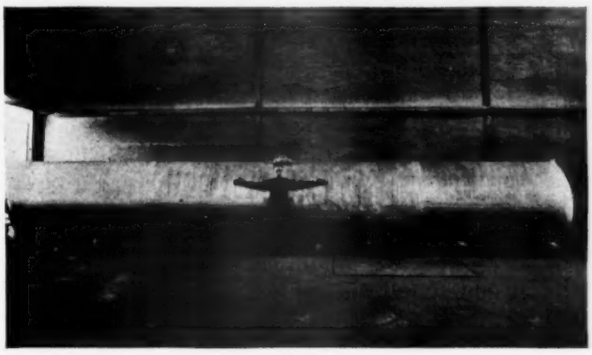
In the ordinary process, the work material is made positive and the weld rod, or electrode as it is usually called, is made negative. It is supposed that two-thirds of the heat is generated at the positive electrode. Alternating current is sometimes used, but it is claimed that direct current gives a

Welding 10 in. high pressure oil line in position (operating pressure, 750 lb. per sq. in.; wall thickness 5/16 in.)

more stable arc. Also the advocates of direct current point out that a better distribution of heat can be obtained, in that the work material being heavier than the weld rod, requires and can absorb more heat than the latter. This may or may not be an advantage. In using bare electrodes and direct current, the arc conditions are apparently much better when the work material is made positive. Hereafter this method of connecting will be referred to as "standard" and the opposite as "reverse polarity." In this type of metallic arc welding it is necessary to maintain a very short arc, from ⅛ to ¼ in., in order to reduce the contamination of the deposited metal with atmospheric oxygen and nitrogen. The diameter of the elec-

trodes varies from 3/32 to ¼ in., depending upon the size of the work. The lengths usually are from 10 to 14 in. The currents used range from 50 to 300 amperes according to the size of electrode, and the arc voltages, from 20 to 30 volts.

The phenomenon of the electric arc was discovered and named by Sir Humphry Davy in the



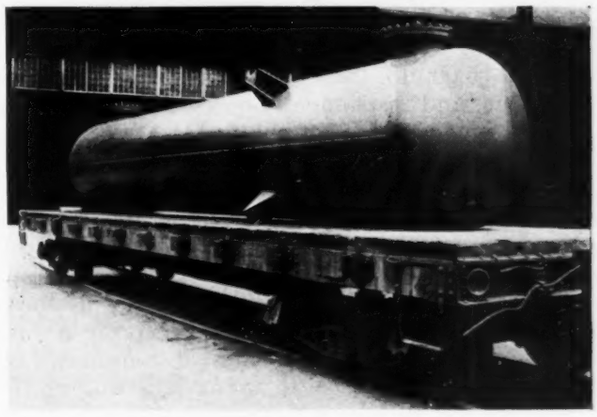
Baffle tower, 5 ft. dia. by 30 ft. long with ¾ in. shell fittings, electrically butt welded throughout.

year 1801. In separating two carbon pencils carrying a strong current, he observed that the current continued to flow, being conducted from one pencil to the other by an arc or stream of incandescent vapor of carbon. The temperature of the electric arc is the highest obtainable. Some investigations have given for the crater of the positive carbon, a temperature of about 6700 deg. fahr. for the end of the negative carbon, about 4500 deg., and for the arc itself about 7800 deg. Evidently the maximum temperature here obtained reaches the vaporization point of carbon and greatly exceeds that of iron which is around 4500 deg. fahr.

Following Faraday's discoveries and the perfection of the dynamo, the carbon arc was used for lighting purposes. The first successful arc light was brought out in the year 1881. Moisson's electric furnace started many investigators to experimenting with the electric arc in the fusing and welding of metals. Werderman so experimented directing the arc formed between two carbon electrodes, against the metal to be fused by means of a jet of air. In 1890, Zerener invented the electric blow-pipe. In this, the arc was deflected to a point by means of an electro-magnet connected in series with the arc. This apparatus was used to some extent in Europe in the repairing of broken castings. In 1881, De Meritens dropped the use of one of the carbon electrodes, replacing it with the work itself. About four years later, Bernardos, a Russian, developed this method into a practical process which has since undergone few changes. About the year 1890, Slavianoff introduced a method of electrical casting in which he dropped the use of both carbon electrodes substituting therefore a metal melt bar for the negative and the work itself for the positive. This was the beginning of metallic arc welding. Kjellberg, in Sweden, assisted greatly in the development of this process. He was the first to use coated electrodes in attempting to obtain a reducing condition around the arc in order to prevent oxidation of the weld metal.

Carbon arc welding is not so commonly used since the improvement of the metallic arc process. It is still employed in foundries for filling in blowholes and repairing cracked castings. Where such parts are subsequently annealed, the physical properties of the weld metal satisfy the requirements for a cast material. In manual operation, the welder is subjected to more discomforture than in the metallic process. The necessity of handling both the carbon electrode and a separate rod of filler material provents the relief attending ambidextrous manipulation of the electrode. The deposited metal is subject to a variety of ills such as, occluded gases, carbonization and oxidation of the steel. The preponderance of the carbon vapors in the arc leads to an excessive introduction of this element into the weld metal. Particularly with short arc lengths, this results in a hard and brittle product. On the other hand the extreme arc lengths necessary to prevent carbonization, nullify the theoretical shielding afforded by the carbon vapors against oxidation and nitrogenization of the fused metal. At the present writing, the carbon arc process is not popular because welds so made are very low in ductility, impact value, and resistance to corrosion.

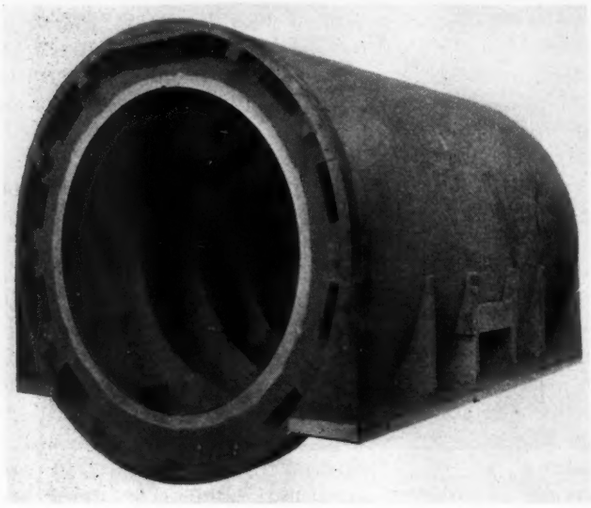
The poorest welds yet made were probably produced by the metallic arc process. In spite of this,



Storage tank of sheet aluminum with oxy-acetylene welded joints.

its many evident advantages and possibilities were early recognized. In late years, it has been the recipient of more intensive study and development than any other welding process. The latest developments in this art will be discussed later. The following applies to the ordinary method generally known as bare wire welding. This method is equally applicable to repair and production work. Except in connection with extremely thin plate, it is more commonly used than any other method, particularly in connection with the low and medium carbon tank and structural steels. It is also used in welding cast steel, cast iron, and some of the alloy steels and non-ferrous metals. The weld-

ing can be done in almost any position. By laying successive beads, it is used in building up heavy section deposits. The quality of bare wire welds, though often satisfactory for the work at hand, is universally poor in comparison with the base material. The quality, such as it is, depends almost entirely upon the skill of the operator. Even ex-

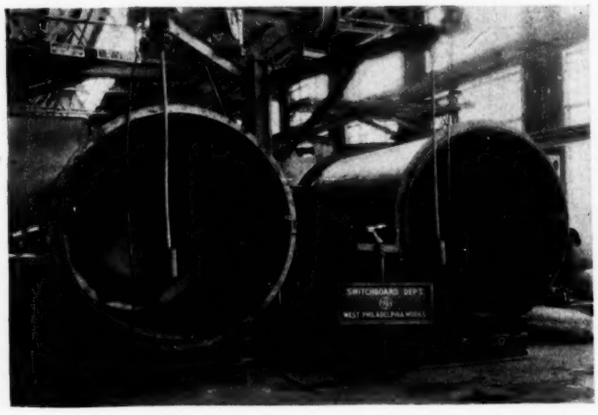


All electric welded stator frame.

perts cannot produce consistent results. Under the best conditions in the welding of boiler plate material, a joint tensile strength of about 50,000 lb. per sq. in. can be obtained as compared to 55,000 to 65,000 lb. for the plate. In ductility, impact value, and resistance to corrosion such welds are even worse. Most of the welds are extremely porous and contain oxides and nitrides to such an extent that the metal is brittle and poorly resistant to corrosive agents. No one has been able to eliminate these defects in bare wire welding, although extremely short arc lengths and various current characteristics have been tried. In spite of these well known facts, this method is receiving a vast usage. In many cases of limited requirements, such usage is justifiable, in many it is a doubtful procedure, and in others it is inexcusable.

The many factors present in electric arc welding have been studied by various investigators in the development and improvement of this art. Among these are: the chemical and physical properties of the electrode or filler material; the diameter and length of electrode; the current density and arc voltage; the length and stabilization of the electric arc; the control of variables in automatic operation; the shielding of the arc in various atmospheres; and the use of fluxing or slagging agents. Good, clean weld rods of chemical analysis suitable for the base material are of first importance. But many of the claims that have been promulgated concerning special electrodes can be classified as a species of humbuggery. Practically all welders have put the blame for poor results on the electrode, that being the easiest course to take. Not being able to meet the argument, many manufacturers have stooped to witch-craft in the production of welding electrodes. In bare wire welding, small diameter and short length weld rods give the best results. Under other conditions, large diameter and long length electrodes are used in making excellent welds. Some authorities have claimed that a maximum current density is the key to quality welding. Under certain conditions, this may be true. Under others, perfect welding can be obtained with current densities entirely at variance with those stipulated. The same disagreement obtains concerning the importance of arc lengths and arc voltages. The stabilization of the arc is undoubtedly important. The light covering put on many electrodes may assist in this, but none of these produce really good welds. The control of the many variables has been attempted in so-called automatic welding machines. This has resulted in considerable economy, but automatic welding, in itself, has led to little improvement in quality.

One of the most beneficial developments has been the shielding of the arc against the most harmful gases. This is being done by shielding the arc in an atmosphere of hydrogen or hydrocarbon gases. Together with automatic operation, this has been applied to both the carbon and metallic arc methods. This produces welds which are much superior to those obtained in the unshielded carbon arc and in the use of bare or lightly coated electrodes. These shielding processes are used considerably in the manufacture of pipe and tanks of the lighter plate thicknesses. They



Jib crane semi-automatic welder and tank rolling device for arc welding circular flanges and bottoms on oil circuit breaker tanks.

have not proven successful in the welding of heavy plates. In these processes, the shielding is not complete. All gases are more or less soluble in the molten metal and are more or less harmful. If not eliminated before solidification, they will at least produce porosity in the weld metal.

The atomic-hydrogen process is a special development of shielded arc welding. Hydrogen gas is fed into an alternating current arc established and maintained between two tungsten electrodes. The manipulation of this arc in welding is similar

Arc welded machine for welding ¼ in. thick fins on each side of 4 in. dia. tubes. This machine handles tubes up to 30 ft. long.

to that of a gas welding torch. The filler material is handled in the same manner. The temperature obtained is said to be in the neighborhood of 7200 deg. fahr. The arc tip is very small and pointed. The quality of welds made by this method is admirable, being homogeneous, ductile, and without porosity. It is a particularly suitable method for welding thin gage sheets, but has not been successfully applied to heavy plate welding. Many of the alloys and metals, heretofore considered unweldable by the arc method, are successfully handled by this process.

All of the above named factors are of great importance and must be considered in their proper relation in the production of good welds. However, the most important factor in obtaining deposited metal of desired properties, is the shielding and protection of the arc and the liquid pool of metal against all harmful gases. So far the best results have been obtained by the use of the so-called heavily covered electrodes. Such electrodes were first used by Kjellberg about the year 1905. The entire function of the electrode covering has not been satisfactorily explained. It is apparently twofold, one being the physical and chemical shielding of the metallic vapors from the oxygen and nitrogen in the air, and the other being the production of a flux or slag coating over the liquid pool of metal to prevent surface contact with the air. It is thought that this surface covering prevents the absorption of the atmospheric gases and at the same time delays surface chilling of the fused metal. It thereby aids in the elimination of shielding gases dissolved in the molten pool. But so numerous are the contributing factors and so scant the knowledge of the chemistry and structure of matter at such elevated temperatures that it is not possible to justify dogmatic assertions as to what is taking place within and around the electric arc.

•

American Welding Society Annual Meeting will be held April 27, 28 and 29, in the Engineering Societies Building, 33 West 39th Street, New York City. Many interesting and timely papers have been prepared to be presented at the meetings. Thursday, the 28th of April, the eleventh annual dinner of the Society will be held at the Hotel New Yorker; a fine educational and entertainment program has been prepared.

•

Blaw-Knox Company, Pittsburgh, recently closed an agreement with the Western Pipe and Steel Company of San Francisco and Los Angeles for the organization of a new selling company called the Blaw-Knox & Western Pipe Corporation. The Western Pipe & Steel Company is to manufacture the Blaw-Knox products and sell them through the above-mentioned new organization on the Pacific Coast. The two companies will share equally in the ownership of the new company.

Combined Low Temperature Carbonization and Combustion

By DAVID BROWNLIE, LONDON

In previous articles, Mr. Brownlie has described various European processes for the low-temperature carbonization of coal. This article describes and presents performance data on the Pintsch process for combined carbonization and combustion of which there are about a dozen plants operating. Most of these plants are located in Central European countries where the fuel conditions are favorable to such a process.

THE economic possibilities of combined low temperature carbonization and combustion, particularly with respect to large power stations, have created a wide interest in the various processes developed for this purpose. In this practice, the coal or other fuel, instead of being burned in the raw state, is first subjected to low temperature carbonization in retorts either integral with the actual boiler setting, or adjoining, all the low temperature fuel, together with the residual gas, being burned under the boilers. The equipment used provides for the separation of the valuable low temperature tar, as well as scrubbing for light oils if necessary.

The net result for a given power output is to require the use of say 25 to 30 per cent more coal, in return for which there is obtained an average yield of about from 16 to 20 Imperial gal. of tar per ton (2240 lb.). This tar can then be worked up in any desired manner, and generally gives, on fractionation 2 gal. of crude light oil, in addition to a further 2 gal. scrubbed from the gases while on the average about 50 per cent of the total volume is available for Diesel engine use. A further field, especially in coal or iron and steel establishments, is the efficient use of low-grade fuels, which on carbonization are converted into a more suitable product for combustion in the ordinary smaller and medium-sized water-tube boiler plant, as well as the recovery of the tar.

This question of course is not so important in the United States, but the situation is very different in countries such as Great Britain, Germany, France, and Japan which possess little or no petroleum.

The resulting low temperature fuel can be burned according to two general methods, that is either on traveling grate stokers or as pulverized fuel, and, when the retorts are integral with the boiler plant setting, the sensible heat of the carbonized fuel is utilized.

At the present time there is only one process of combined low temperature carbonization and combustion being used with integral retorts on a fairly large scale, namely, that of the firm of Julius Pintsch A.G. of Berlin. However, the large-scale experimental installation of the Hereng process in France, described by the author in a previous issue of COMBUSTION, continues in operation and there has now been installed a small plant at the Mines de Lievin in France.

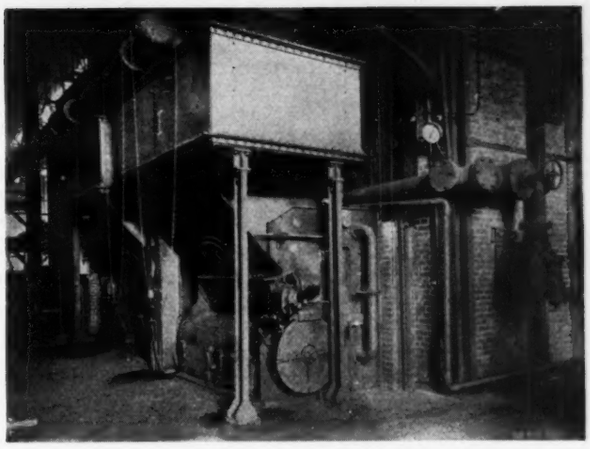
Unfortunately the McEwen-Runge process of combined low-temperature carbonization and combustion of coal in the pulverized condition at the Lakeside Station, Milwaukee, remains closed down, and not much has been heard lately of the Wisner or dual carbocite carbonization process at the Philo Station, Ohio, which uses rotary cylindrical retorts for the carbonization. Also the Babcock or Merz & McLellan plant at the Dunston Power Station, Newcastle-on-Tyne, Great Britain, representing the most extensive experience, has now temporarily been closed because of the reduced demand for electricity in the Newcastle area, due to the trade slump. This process now operates mainly on the principle of a separate adjoining retort of the vertical mechanically-continuous type, with internal heating by combustion gases and steam at a temperature of about 1000 deg. fahr., the low temperature fuel being quenched and then burned on chain grate stokers. In this case, it has been concluded that it is better to lose the sensible heat in the carbonized fuel and to operate the retort at one continuous speed, representing the best efficiency, than to vary the retort throughput according to the fluctuating steam demands of the boilers.

In connection with the Langerbrugge Power Station, Ghent, there still continues to run, in an adjoining establishment two low-temperature carbonization plants, according to the Thyssen rotary retort process, and the Salerni or Salermo process. The retort in the latter case consists of a row of steel troughs heated from underneath and contain-

ing paddle agitators, the coal flowing sideways from one retort to another while being carbonized. In these applications also both the smokeless fuels are quenched and taken across to the power station, where they are burned on chain grate stokers and also as pulverized fuel, along with the gas.

Certainly, however, the Pintsch process, originated in 1917, represents the most determined attempt that has been made to utilize this principle of combined low temperature carbonization and combustion. The principle consists essentially in submitting coal, lignite briquettes, or any other fuel to treatment in a comparatively short, closed, vertical retort of considerable width, operating on the mechanically-continuous principle. This retort is attached to the front of a water-tube boiler or other furnace, which is fitted with traveling grate mechanical stokers. That is, the retort replaces the ordinary coal hopper and is internally heated by means of part of the very hot gaseous products of combustion taken from the fires about the middle of the travel of the stoker.

The raw fuel is supplied to the top of the setting by means of a traveling conveyor or other suitable device, so that the retort is kept completely filled with the charge by means of a gas-tight feed arrangement, and the residual carbonized fuel is withdrawn continuously at the bottom, the charge traveling downwards by gravity and passing direct in the red-hot condition on to the traveling grate stokers, the speed of which regulates the throughput of the retort. At the bottom of the latter, the heated gases enter from the combustion chamber at about 1000 to 1250 deg. fahr., corresponding to a volume of approximately 35,000 to 45,000 cu. ft. per ton (2240 lb.) of coal or other average raw fuel, this being from 10 to 20 per cent of the total gases from the stokers. All the mixed gases and vapors

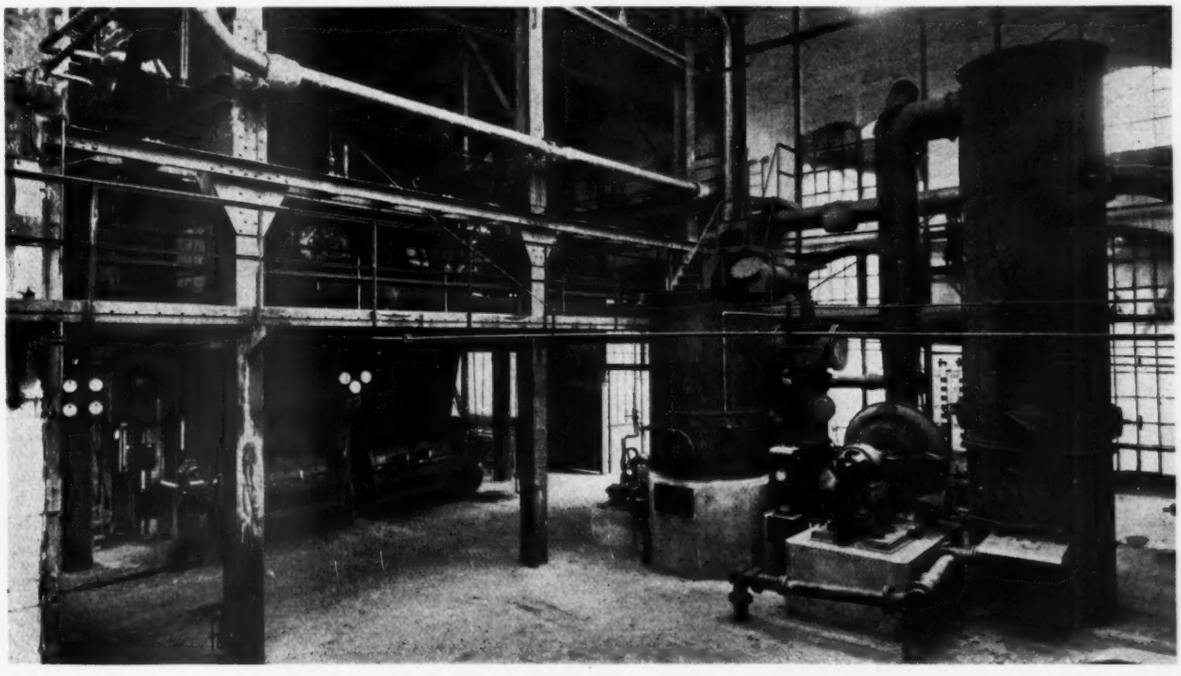


Original Pintsch plant installed at the Lichtenberg power station, Berlin.

are drawn off from the top of the retort through a pipe circuit containing a mechanically-operated suction feed. Generally the total capacity of the retort for a standard industrial water-tube boiler of say 50,000 lb. evaporation per hour is about 17 to 18 tons. This corresponds to a time of travel for each particle of approximately six hours. The mixed gases and vapors leave the top of the retort setting at only about 212 deg. fahr.

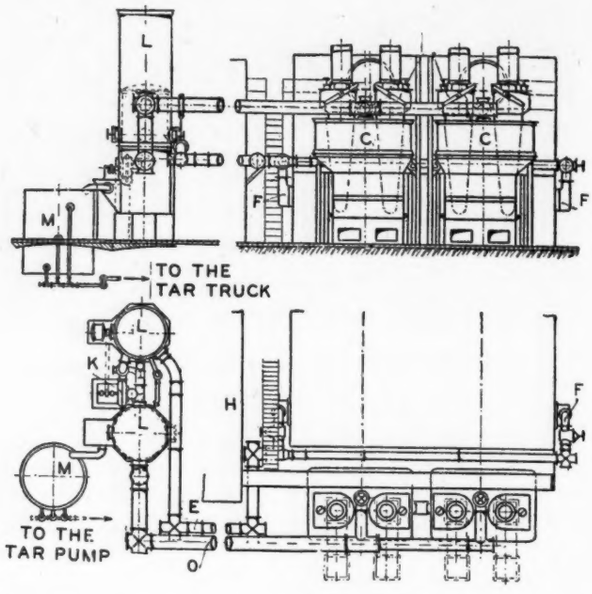
There is also included a simple type of cooling and condensing plant to which the gases and vapors are discharged, the tar being separated as usual by condensation and the dirty gas then burnt direct in the boiler setting. If necessary, however, as stated, the gases can also be scrubbed for the light oils, although this is not generally worth while unless high-grade bituminous coal is used.

The yields, of course, depend upon the individual circumstances, but with normal coal there is ob-



Pintsch plant installed at Altona station of the German state railways.

tained from 16 to 20 gal. of tar per ton, while the residual smokeless fuel passing direct to the stokers is approximately 70 per cent of the weight of the



H Boiler settings
C Retorts
F Gas inlet to boiler combustion chambers
O Gas and vapor off-take pipe from retorts
L Water-cooled condensers for tar
M Tar storage tank
K Motor driven exhauster
E Gas pipes from condenser leading to the boiler plant

Elevation and plan of Pintsch plant, for two boilers, at the Lichtenberg station, Berlin.

coal. With lignite briquettes the yields are slightly less, and the same applies to low-grade coals such as are used at collieries.

The first large scale Pintsch plant was erected in 1919 at the Municipal Electricity Station of Lichtenberg, near Berlin (which has now been closed down), and consisted of two Steinmuller water-tube boilers, each of 5380 sq. ft. heating surface, equivalent to a normal evaporation of 40,000 lb. of water per hour. At the present time there are about one dozen plants operating in Germany, Norway, Brazil, and the Prinzengrube and Trauscholdsegen colliery districts in Upper Silesia. In the latter case. the plants have water-tube boilers, mostly of medium size averaging from 5000 to 6000 sq. ft. heating surface, equivalent to a normal evaporation of say 40,000 to 50,000 lb. per hr.

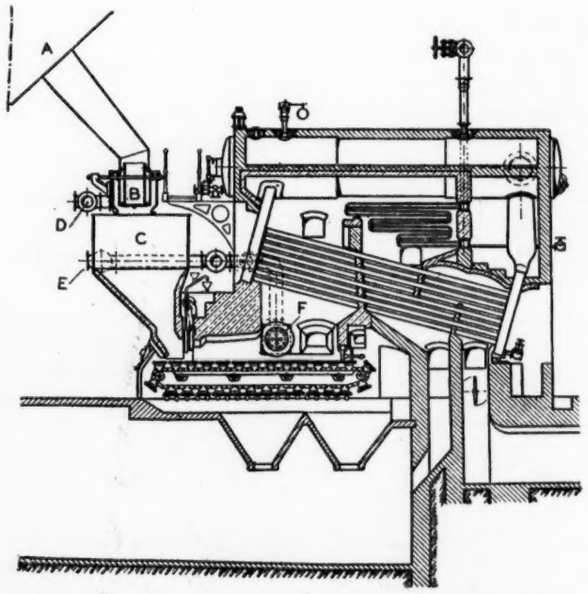
Two of the most interesting Pintsch plants in Germany are at the Altona Power Station on the Elbe and the Brandenburg West repair shops at Kirschmöser, both belonging to the Berlin State Railways. In the latter case the water-tube boiler equipped has a heating surface of 5382 sq. ft. and is fired by two natural-draft chain-grate stokers and a Pintsch retort using lignite briquettes, made as usual in "sausage" or extrusion presses by predrying the raw lignite and compressing without a binder at high pressures. The total grate surface is 184 sq. ft., while the steam pressure is 191 lb. per sq. in. The superheaters have 1910 sq. ft. heating surface.

At the Altona Power Station there is a somewhat similar installation of one water-tube boiler of 6458 sq. ft. heating surface, low temperature carbonization retort, and two chain grate stokers of 222 sq. ft. grate surface. The steam pressure is 206 lb. per sq. in. A superheater of 1614 sq. ft. of surface is installed and there is also a feedwater economizer. Both plants have the usual arrangement of condensing and other equipment for the recovery of the tar.

The results of a most detailed and elaborate series of tests carried out upon the Pintsch plant at Altona are contained in a dissertation for a Doctor of Engineering Degree of the Technical High School, Berlin, by Dr. Heinrich Johannes Siebel of Kiel. This is entitled "Beitrag zur Urteergewinnung aus Braunkohlenbrikette in Verbindung mit Dampfkesselfeuerungen," and is published for private circulation by Wilhelm Knapp of Halle-Saale (1931), having been presented July 3, 1929.

This paper also includes detailed figures of the Pintsch No. 1 plant at Brandenburg West. In this connection I have to thank Dr. Heinrich J. Siebel for a copy of this publication, and also for his courtesy in supplying additional information, as well as the photographs of the Altona plant.

The following is a summary of the essential fig-



A Coal hopper
B Coal feed
C Retort
D Mixed gas outlet leading to condensers
E Hot gas inlet
F Outlet of hot combustion gases

Original Pintsch plant at the Lichtenberg power station, Berlin, which operated Steinmuller boilers.

ures given by Dr. Siebel of 13 separate tests of from 7.5 to 9.25 hr. each and one shorter test of only 4 hr., all carried out at the Altona plant. Similar figures are given for five tests at Brandenburg West, of from 23.5 to 30.75 hr. each. At Altona, seven varieties of lignite briquettes were used, and at Brandenburg West one variety, having the following proximate analysis:—

	Altona (13 samples)	Brandenburg West (5 samples)
Fixed Carbon, per cent.....	27.70—36.60	27.95—29.86
Volatile Matter, per cent....	39.58—47.10	45.03—47.47
Ash, per cent.....	6.34—12.80	10.50—11.38
Moisture, per cent.....	13.14—17.70	13.08—15.70
Total	100.00	100.00
Heating Value:		
(1) Higher value, B.t.u. per lb.....	9018—9985	9288
(2) Lower value, B.t.u. per lb.....	8424—9369	8424—8946
Tar Yield (assay test).....	8.35—14.84	12.20—14.05

The average performance figures for the two retorts on each plant were:

	Altona (13 tests)	Brandenburg West (5 tests)
1. Raw lignite briquettes carbonized and burnt per hour on the boiler, along with the gas.....	7,128 lb.	4,400 lb.
2. Water evaporated to steam per hour on the boiler	32,560 lb.	22,000 lb.
3. Tar yield (dry) per hour on the boiler	495 lb.	473 lb.
4. Yield of mixed gas per boiler per hour, as burnt in the combustion chamber	174,809 cu. ft.	134,903 cu. ft.

This corresponds respectively to an evaporation of 4.50 lb. and 3.60 lb. of water per lb. of lignite briquettes, and a production of 6.9 per cent and 7.6 per cent of tar by weight of the briquettes.

The demand for steam fluctuates however, so that the evaporation on the Altona boiler varies within the range of 23,670 to 35,860 lb. per hour, and on the Brandenburg boiler, 20,020 to 23,760 lb. Other operating conditions at Altona were 212 to 252 deg. fahr. feedwater temperature, 224 to 240 lb. per sq. in. steam pressure, 660 to 742 deg. fahr. superheated steam temperature, 9.8 to 13.3 per cent CO_2 in the flue gases, and 552 to 720 deg. fahr. in the waste combustion gases leaving the boiler plant.

At Brandenburg West some of the corresponding figures were 212 deg. fahr. feedwater temperature, 219 to 230 lb. steam pressure and 680 to 705 deg. fahr. superheated steam temperature.

The average composition of the mixed low temperature corbonization and waste combustion gases as burned in the boilers was as follows:—

	Altona (13 tests)	Brandenburg West (5 tests)
CO, per cent.....	11.1—15.9	14.6—18.0
H_2, per cent.....	8.2—14.3	13.4—14.5
CH_4 (etc.), per cent.....	2.1— 5.3	2.4— 6.3
Unsaturateds, per cent....	0.6— 1.9	0.6— 1.5
CO_2, per cent.....	6.2—13.8	8.6—10.8
O_2, per cent.....	4.2— 8.8	1.6— 3.8
N_2 (difference), per cent..	50.5—58.4	50.0—54.3
Total	100.00	100.00
Heating Value:		
(1) As obtained, B.t.u. per cu. ft.....	100—155	140—173
(2) Calculated on air-free gas, B.t.u. per cu. ft.	150—226	170—199

The principal figures for the low temperature tar are:

	Altona (13 tests)	Brandenburg West (5 tests)
Water content of crude tar, per cent	7.0 —54.0	10.0 —30.0
S. G. at 44 deg. cent.....	0.942— 1.020	0.930— 0.947
Dust, per cent.....	0.62 — 2.80	1.19
Crude oil content, per cent..	20.00 —33.20	22.88
Creosote, per cent.....	12.30 —24.00	14.16
Paraffin wax, per cent.....	6.20 —13.70	13.10

This tar is all used on the German State Railways for making oil-gas for lighting the railway carriages instead of using petroleum. The general operation of the plants seem to be very satisfactory.

•

Boiler Feedwater Investigations

A story of the boiler feedwater conference recently held by the joint Research Committee on Boiler Feedwater Studies, will appear in the April NEWS of the Ohio State University Engineering Experiment Station, Columbus, Ohio. A copy of the bulletin may be had by writing to the University.

•

Goulds Pumps, Inc., Seneca Falls, N. Y., announces the appointment of Hamilton Garnsey, Jr. as works manager. Mr. Garnsey has been with the Goulds organization since 1923, and has reached his present appointment after a series of progressive promotions, his appointment immediately preceding the present one having been that of assistant to the president.

•

The Massachusetts Institute of Technology announces the appointment of Dr. Vannevar Bush, professor of electrical engineering, as vice president of the institute and dean of engineering as well as a member of the corporation. Dr. Bush is well known for his achievements in power system research and technical education.

•

Sheldon, Morse, Hutchins and Easton, recently formed to handle industrial marketing and the economic problems connected with scientific industrial research, have moved their offices to the Graybar Bldg., 420 Lexington Ave., New York City. The principals of the organization are H. H. Sheldon, H. A. Morse, L. W. Hutchins, and W. H. Easton.

Some Notes on the Performance of Boiler Furnaces*

By A. T. BROWN
United Engineers and Constructors, Inc.
Newark, N. J.

This paper presents an empirical method for determining furnace outlet temperatures based principally on a number of temperature measurements made on several installations. As the author points out the co-efficient of heat resistance used is limited to those types of waterwalls and furnace designs on which the readings were taken. Therefore, the formula cannot be applied to a unit of different design and construction until readings are taken on a comparable installation which will permit the determination of the correct co-efficient. In the conclusion the author questions the sufficiency of the data but states that they will at least give comparative results and permit consideration of the method.

THE author was requested to prepare this paper with the idea that the method and data contained in it were of sufficient interest to warrant presentation in its present form, which is admittedly incomplete, due to lack of sufficient data.

This paper covers an attempt to determine the actual temperature at the outlet of a boiler furnace from the experimental data available to the author. No claims are made by the author that this method is any more accurate than the Stefan-Boltzmann law, which is commonly used in calculating furnace temperatures, and perhaps the method explained warrants attention only on account of its simplicity. Initially, the author endeavored to find a relation for a particular boiler furnace between the total heat input to the furnace and the temperature at the furnace outlet, all based upon its overall performance determined by experiment without reference to the Stefan-Boltzmann law, and, later, data on other furnaces were collected, in order to see how closely they followed the same general law.

It is necessary that the observed furnace-outlet temperatures shall be accurately taken and that combustion must be complete, in order for this method to give accurate results. It is to be hoped that this method may be of use to designers of furnaces, and later may be modified or refined, if the actual test results show that changes are necessary. Obviously the data presented must be used with proper caution and must be considered at present as yielding only comparative results. All of the boiler furnaces covered in this study have about the same saturated steam temperature, namely 400 to 450 deg. fahr., and it is not known if furnaces with higher steam temperatures will follow the same performance curve. The fundamental test data which initiated this study, and on which the calculations are based, were taken from tests on 2360-hp. stoker-fired cross-drum boilers, which were originally equipped with brick settings.

At a later date all of the rear walls and a small percentage of the side walls were provided with water-cooled surfaces, and still later new superheaters were installed and the equivalent of one row of boiler tubes was removed from the boiler section below the superheater and toward the furnace.

Unfortunately, the furnace temperatures in the tests of these boilers were all calculated from the observed gas temperatures taken below the superheater.

The data deduced from the performance of these boilers seem to be consistent and indicate that the heat absorption in the furnaces with total and partially water-cooled furnaces all follow the same general law (Fig. 3), and all points follow closely the same curve. Doubtless other charts can be prepared to cover various styles of furnaces with bare-tube or refractory-covered cooling surfaces, in case the present one does not apply to all designs with sufficient accuracy, and it certainly should not apply to a furnace with refractory-covered tubes.

In order to calculate the amount of heat absorbed or given up by furnace gases after combustion is complete, Fig. 1 has been prepared from an analysis of a typical bituminous coal. This chart gives both the instantaneous and mean specific heats for given temperatures and has been prepared from data taken from Arthur D. Pratt's book on "Prin-

* Presented before the Metropolitan Section of The American Society of Mechanical Engineers, New York, March 22, 1932.

ciples of Combustion in the Steam Boiler Furnace," published by the Babcock & Wilcox Company (second issue, 1920).

In developing the formula for the specific heat of furnace gases, the CO_2 and water-vapor constituents have been assumed to have specific heats which bear a linear relationship to the temperature, and as these constituents are usually a small percentage of the total, this assumption will cause no error of any great magnitude.

Specific Heats of Furnace Gases and Theoretical and Actual Temperatures of the Products of Combustion

Where no powers of the temperature higher than unity are present, in the formula which expresses the relationship between the instantaneous specific heat and the temperature of a given gas, the approximate instantaneous specific heat of furnace gases may be calculated as follows:

H_1 = Mean specific heat B.t.u. per lb. per deg. fahr. over definite range of temperature (B to T_1) or (T_1 to T_2). (See below.)
C_p = Instantaneous specific heat at any temperature (t).
t = Temperature of gases.

If $C_p = a + bt$, where a and b are experimental constants, then the mean specific heat (H_1) between t_1 and t_2 =

$$a + \frac{b}{2}(t_1 t_2) \text{ and } b = \frac{2(H_1 - a)}{t_1 + t_2} \quad \ldots\ldots(1)$$

Using Pratt's data we have the following values of a and b for various gases, assuming average straight lines in the cases of CO_2 and water vapor:

	a	b
Nitrogen	0.234	0.0000210
Oxygen	0.215	0.0000192
CO_2	0.205	0.000050
Water vapor	0.454	0.000048

Assume as typical the following coal analysis as fired (bituminous coal):

	Per cent
Carbon	77.6
Hydrogen	4.7
Oxygen	3.9
Nitrogen	1.0
Sulphur	1.7
Ash	8.1
Moisture	3.0
	100.0
B.t.u. value as fired	13,900

For an average condition assume 14 per cent CO_2 by volume dry products of combustion. Then the total weight of the products of combustion is made up as follows for 1 lb. of coal as fired:

	Per lb. coal	Per cent
CO_2	2.882 lb.	19.7
O_2	0.761	5.2
N_2	10.550	72.0
Moisture	0.446	3.1
	14.639	100.0

On this basis for one pound of products of combustion, we have the following approximate formula for 14 per cent CO_2:

14 per cent CO_2:	Lb.	a	b
Nitrogen	0.720	0.1685	0.0000151
Oxygen	0.052	0.0112	0.0000010
CO_2	0.197	0.0404	0.0000099
Water vapor	0.031	0.0141	0.0000015
	1.000	0.2342	0.0000275

Formula for average furnace gas 14 per cent CO_2:

$$C_p = 0.234 + 0.0000275\ t \quad \ldots\ldots(2)$$
$$H_1 = 0.234 + 0.0000138\ (t_1\ t_2) \quad \ldots\ldots(3)$$

Also the following apply for other percentages of CO_2:

10 per cent CO_2:	Lb.	a	b
Nitrogen	0.733	0.1715	0.00001540
Oxygen	0.101	0.0217	0.00000194
CO_2	0.144	0.0295	0.00000720
Water vapor	0.022	0.0100	0.00000106
	1.000	0.2327	0.00002560

12 per cent CO_2:	Lb.	a	b
Nitrogen	0.727	0.1701	0.00001526
Oxygen	0.076	0.0164	0.00000146
CO_2	0.171	0.0351	0.00000855
Water vapor	0.026	0.0118	0.00000125
	1.000	0.2334	0.00002652

16 per cent CO_2:	Lb.	a	b
Nitrogen	0.715	0.1673	0.00001501
Oxygen	0.028	0.0060	0.00000054
CO_2	0.223	0.0458	0.00001115
Water vapor	0.034	0.0155	0.00000163
	1.000	0.2346	0.00002833

In order to apply these data to furnace gases, we proceed as follows. If all of the heat in the fuel

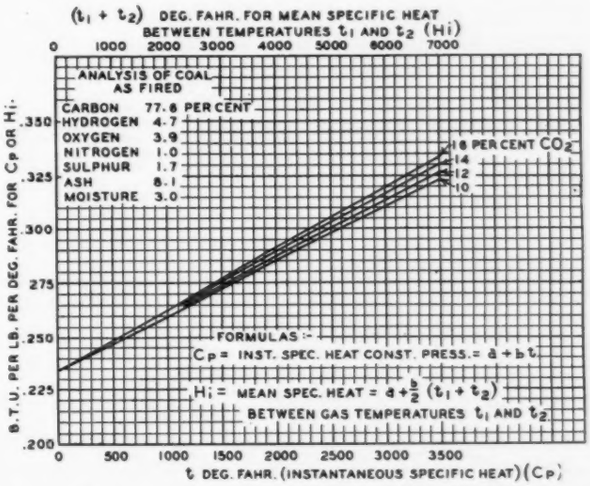

$(t_1 + t_2)$ DEG. FAHR. FOR MEAN SPECIFIC HEAT BETWEEN TEMPERATURES t_1 AND t_2 (Hi)
0 1000 2000 3000 4000 5000 6000 7000
ANALYSIS OF COAL AS FIRED
CARBON 77.6 PER CENT
HYDROGEN 4.7
OXYGEN 3.9
NITROGEN 1.0
SULPHUR 1.7
ASH 8.1
MOISTURE 3.0
16 PER CENT CO_2
14
12
10
FORMULAS:-
C_p = INST. SPEC. HEAT CONST. PRESS. = $a + bt$
Hi = MEAN SPEC. HEAT = $a + \frac{b}{2}(t_1 + t_2)$
BETWEEN GAS TEMPERATURES t_1 AND t_2
B.T.U. PER LB. PER DEG. FAHR. FOR C_p OR Hi
.350
.325
.300
.275
.250
.225
.200
0 500 1000 1500 2000 2500 3000 3500
t DEG. FAHR. (INSTANTANEOUS SPECIFIC HEAT) (C_p)

Fig. 1—Furnace gases—mean and instantaneous specific heats.

were absorbed by the furnace gases and there were no radiation or convection, the temperature of the furnace gases would rise to a theoretical temperature (Tt) which can be calculated quite easily. Actually, due to the fact that a considerable amount of the heat is radiated to the water-cooling surfaces in the furnace and also that there is heat transfer by convection, the outlet temperature of the furnace gases (Ta) is much lower than the theoretical temperature. The difference in the heat content of the

gases at (Tt), the theoretical temperature, and (Ta), the actual temperature of the furnace gases at the furnace outlet, is the actual total heat absorbed in the furnace. The balance of the heat in the actual temperature (Ta) of the furnace gases leaves the furnace and is available for use in the boiler, superheater, etc.

Let T_t = Theoretical temperature to which products of combustion would be raised if there were no surfaces present which absorbed radiant heat and no heat could escape from the furnace.
T_a = Actual temperature of furnace gases at the outlet of the furnace.
t = Temperature of water and steam inside the water-cooled surfaces and boiler tubes.
B = Basic temperature from which products of combustion are raised.
H_1 = Mean specific heat B.t.u. per lb. per deg. fahr. (T_t to T_a).
G = Lb. of gas per hour, total.
S = Square feet of projected area of exposed water-cooled surfaces, including boiler tubes. (The projected area is used because it is simple, and it is not known if better results could be secured by using other areas. At any rate it seems to be satisfactory for use as a measure.)
r = Experimental coefficient of heat resistance from furnace-outlet temperature to temperature of water in tubes = temperature difference (temperature furnace outlet to temperature of water in tubes) + B.t.u. heat absorbed per square foot (projected area) of radiant-heat-absorbing surface per hour.

Perhaps a better name for this co-efficient would be simply "Ratio terminal heat head to the B.t.u. absorbed per square foot (projected area) per hour," as the transfer of heat may not be accomplished in the ordinary sense of convection heat transfer. There is one important thing to note, and that is the temperature difference is the terminal difference in temperature, and not the difference between the average temperature of the furnace gases and the water in the tubes.

Actual Temperature of Gases at Furnace Outlet

$$r = \frac{(T_a - t)\ S}{(T_t - T_a)\ H_1\ G}$$

Then $$\frac{(T_t - T_a)\ H_1\ G}{S} = \frac{T_a - t}{r}$$

or $$ST_a\ H_1\ GrT_a = H_1GrT_t\ St$$

$$\text{(General formula } T_a = \frac{St\ H_1GrT_t}{S\ H_1Gr}) \quad \ldots\ldots (4)$$

In Formula (4), H_1 is the mean specific heat between (T_t and T_a). The total heat absorbed by radiation and convection in the furnace is ($T_t - T_a$) H_1 G.

Theoretical Combustion Temperature

Let H_e = heat value B.t.u. per lb. fuel as fired, which is delivered to the furnace gases. (Allowance should be made for combustible in refuse.)
g = lb. gas per lb. coal as fired.
B = basic temperature from which products of combustion are heated.

$$T_t = \frac{H_e}{g\ H_1} \quad B$$

where H_1 in the mean specific heat between ..... (5)
B and T_t.

In calculating these temperatures T_t and T_a, it is to be noted that the mean specific heat of the gases H_1 from B to T_t in Formula (5) is quite different from that between T_t and T_a, in Formula (4). By reading the specific heats from Fig. 1, both T_t and T_a can be calculated. Of course, for a fuel which has a markedly different analysis from that assumed above, a new chart would be required if great accuracy should be necessary.

From Fig. 2 can be read the total pounds of gas per pound of fuel as fired, for complete combustion for different percentages of CO_2, all for the same analysis of coal as given.

Fig. 3 shows the values of the co-efficient "r," for the various furnaces which have been calculated from the data available from the various tests.

In preparing Fig. 3 it was thought to be unnecessary to allow for losses such as combustible in the refuse, heat of vaporization of water, radiation from the furnace walls to the exterior air, etc. Obviously, in order to determine the heat actually absorbed by the water and saturated steam in the furnace walls, such necessary allowances must be made. However, for calculating the actual temperature of the gases at the furnace outlet, Fig. 3 is to be used.

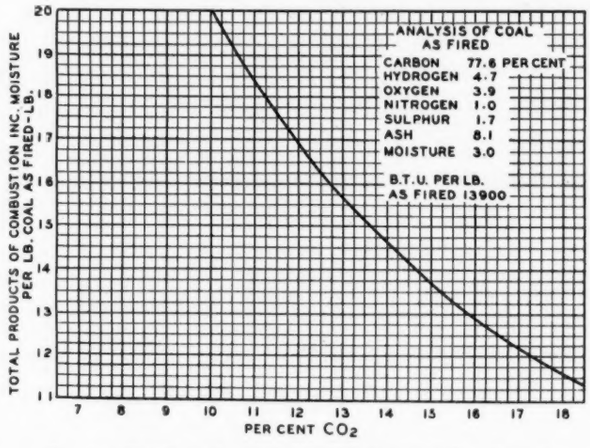


Fig. 2—Total products of combustion per lb. of coal.

Data taken from the article by John J. Grob and Joseph Gershberg in the June, 1931, issue of COMBUSTION on the performance of the No. 81 boiler in the Hell Gate Station of the United Electric Light and Power Company, New York City, which is a pulverized-fuel installation, are plotted on Fig. 3, and the calculations are given in Table 1, which shows by what method the values of "r" for the furnace have been calculated.

With regard to the test data plotted on Fig. 3, the following comments are necessary:

The points plotted from data taken from the paper by Mr. William L. DeBaufre on the English steam generators seem erratic. It is to be noted that all of the other points for other boiler furnaces seem to be fairly consistent with each other, whether they are above or below the average line.

There is a strong probability that the points

TABLE NO. 1—TESTS ON BOILER NO. 81, HELL GATE STATION
(Total projected tube area exposed to radiant heat, 2375 sq. ft.)

Run No.	5	7a	7b	7c	7d	4	3	1	6a	6b	6c	2
Total lb. fuel per hour	18065	.....	19720	.....	.....	20430	19840	27300	.....	30070	.....	30690
B.t.u. per lb. as fired..	13919	.....	13827	.....	.....	14126	14070	13974	.....	14003	....	14066
Millions B.t.u. per hr. furnace input	251.5	273	273	273	273	289	279.3	381.5	421	421	421	432.0
Input per sq. ft. rad. surface	105900	114800	114800	114800	114800	121600	117500	160600	177100	177100	177100	182000
CO_2 per cent.....	13.7	15.8	13.4	12.8	11.2	14.1	14.0	14.0	15.4	13.9	12.5	13.9
Lb. gas per lb. fuel....	14.95	13.1	15.25	15.9	18.0	14.55	14.65	14.65	13.4	14.75	16.3	14.75
Temp. sec. air	161	214	204	197	211	180	185	180	185	184	189	214
T_f	3441	3834	3404	3292	3000	3575	3550	3545	3790	3519	3254	3549
T_a (act.)	1737	1796	1769	1745	1714	1690	1737	1841	1893	1868	1848	1886
t	418	418	418	419	418	418	418	420	423	423	423	422
H_1 (T_f to T_a).....	0.306	0.314	0.3025	0.302	0.2955	0.3065	0.307	0.3085	0.314	0.308	0.3025	0.309
r (furn.)	0.0222	0.0198	0.0216	0.0215	0.0228	0.01757	0.01935	0.01607	0.01455	0.01523	0.01625	0.01495

taken from the pulverized-fuel furnace on the Stirling boiler are somewhat high. Accordingly, if we take the data at its face value, the upper dotted curve would be the performance of a partially water-cooled furnace and the lower dotted curve the performance of a totally water-cooled furnace. This would not be an illogical conclusion, as there probably should be better heat absorption at low inputs with a totally water-cooled furnace than with one that is only partially water-cooled. There are several hundred degrees of difference in the gas temperatures between the upper dotted line and the lower dotted line.

The data from the stoker-fired furnace of the cross-drum boiler with partial and no water cooling seem to be very consistent. However, as the furnace temperatures for these points were all calculated from actual gas temperatures taken below the interdeck superheater, these points have been marked "estimated" on the chart. To the author they seem to indicate clearly that for a given boiler furnace there is a definite relationship between the input to the furnace and the heat absorption, and the aims of furnace designers should be directed to the end of discovering this relationship for different styles of furnaces.

We do not know the exact conditions of the furnaces covered by these various tests, particularly as to the amount of slag present, as gas temperatures in a water-cooled furnace are particularly sensitive to even slight accumulations of slag. This is suggested by Mr. DeBaufre in his paper as a possible reason for the absorption of the Kip's Bay boiler being less than the others.

There is another explanation possible for the observed difference between the Kip's Bay and the Hell Gate furnaces. The Hell Gate furnace is completely surrounded by water-cooled surfaces, and the same thing is true of the Kip's Bay furnace, which has, in addition, a large amount of cooling surface above the furnace, and doubtless this part of the surface above the furnace is not as effective a heat absorber as the wall surfaces of the Hell Gate furnace.

The Kip's Bay furnace, the Stirling boiler furnace, and the furnace of the stoker-fired cross-drum boiler, both with partial water cooling and no water cooling, all show points that are consistent with each other. This seems to be reasonable, as these furnaces might be expected to show consistent performances.

There is one exception, however, and that is the furnace of the cross-drum boiler without water cooling. This shows a performance consistent with the furnace with less effective heat-absorbing surfaces, whereas it would be expected that the surface of the boiler tubes being exposed squarely above the stoker would absorb radiation very effectively. It is possible that there may have been slag accumulations on the boiler tubes or internal scale, which might account for this. Consequently, considerable variation in the plotted data is to be expected, as average gas temperatures in the neighborhood of 2000 deg. are difficult to obtain with accuracy, and we do not know whether the gas weights calculated from the observed percentage of CO_2 are truly representative.

We are not sure that the points for the English steam generators are correct for the points taken from Mr. DeBaufre's paper. Consequently, these points should be considered as simply approximate. Furthermore, the specific heats were read from the chart of Fig. 1, as it appeared likely that they would give sufficient accuracy without going to the trouble of securing a new chart for the specific heats of the gases from the actual fuel used in these tests on the English steam generators. It is to be noted that according to the data presented on Fig. 3, the stoker-fired furnace with 100 per cent water-cooling surface, i.e., completely surrounded, shows a performance slightly above the pulverized-fuel furnace on No. 81 boiler at the Hell Gate Station. Possibly the fins on the furnace tubes of the Hell Gate boiler cause this difference. The author has some data in his possession on actual furnace temperatures, taken at one point at the front of this stoker-fired furnace about 18 in. below the boiler tubes, which show at the higher ratings gas temperatures of 2200 to 2350 deg. fahr., which are about 200 to 300 deg. fahr. higher than the temperatures used as the basis for the data plotted on the chart of Fig. 3.

It is believed that the actual temperature measurements taken at this one point on this boiler are somewhat high, as in a stoker-fired furnace there must be a graduation of gas temperatures all the way from the fuel bed to the boiler tubes, and if the gas samples had been taken at the entrance to

the boiler tubes, the indicated temperatures would have been lower than those reported.

Furthermore, the thermocouple used in this test was enclosed in a porcelain tube with an open end, into which the gases were aspirated. At this point in a furnace, combustion is still in progress, and if the gas is bottled up inside a porcelain tube, the escape of the radiation is hindered, and this again tends to raise the temperature of the gas sample around the thermocouple above the true temperatures, all due to the combustion still in progress.

That combustion is still in progress at the top of a furnace is plainly seen when one compares the heat absorbed by an interdeck superheater with the heat given up by the measured temperature drop of the gases passing over the superheater. The author has made this comparison many times, and the heat absorbed by the steam shows a considerable excess, except at high loads.

In addition, the gas temperature of the gases from the front end of a stoker must be considerably higher than the average, which is a mixture of gases from the entire length of the stoker.

It is obvious that if the observed temperatures are true averages and combustion is complete, the method of this paper will give the true average heat absorption for a given furnace, all determined directly from experiment. However, the author wishes to warn against drawing general conclusions from the data on Fig. 3, as it covers only a few boiler designs and there is some question as to just how near to a true average are the reported

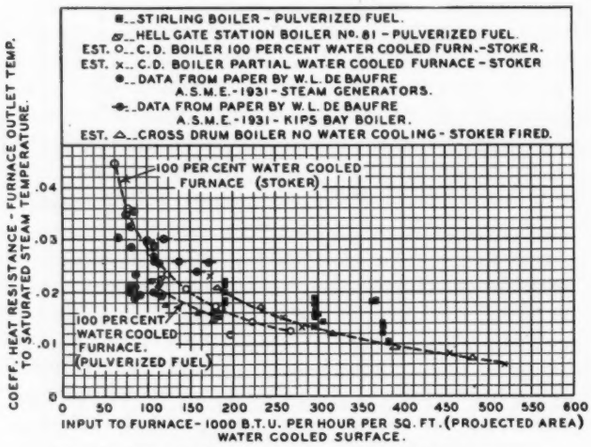

■ STIRLING BOILER - PULVERIZED FUEL.
HELL GATE STATION BOILER No. 81 - PULVERIZED FUEL.
EST. ○ C. D. BOILER 100 PER CENT WATER COOLED FURN.-STOKER.
EST. × C. D. BOILER PARTIAL WATER COOLED FURNACE - STOKER
● DATA FROM PAPER BY W. L. DE BAUFRE A.S.M.E.-1931 - STEAM GENERATORS.
DATA FROM PAPER BY W. L. DE BAUFRE A.S.M.E.-1931 - KIPS BAY BOILER.
EST. △ CROSS DRUM BOILER NO WATER COOLING - STOKER FIRED.
100 PER CENT WATER COOLED FURNACE (STOKER)
100 PER CENT WATER COOLED FURNACE. (PULVERIZED FUEL)
COEFF. HEAT RESISTANCE - FURNACE OUTLET TEMP. TO SATURATED STEAM TEMPERATURE.
.04
.03
.02
.01
0
0 50 100 150 200 250 300 350 400 450 500 550 600
INPUT TO FURNACE - 1000 B.T.U. PER HOUR PER SQ. FT. (PROJECTED AREA) WATER COOLED SURFACE.

Fig. 3—Heat absorption in water-cooled furnaces.

temperatures, and many more points should be secured from furnaces of widely different characteristics and steam pressure before general conclusions are reached. At present these data are offered for study, and the complete justification of their accuracy will come, if ever, after many different types of furnaces have been investigated.

At least one thing is evident. Each style of furnace seems to have a characteristic performance curve depending upon the arrangement of water-cooling surfaces, and it is not to be expected that all of these performance curves should coincide exactly. The task is to gather sufficient experimental data to determine the curves for the various styles of furnaces and for the different steam pressures. What is presented here is only a beginning. If the accuracy of the chart of Fig. 3 is assumed to be sufficient for our purposes, we then can estimate how much heat on the average is absorbed by the water-cooling surfaces in a furnace, which are exposed to radiant heat, and when due allowance is made for the losses which reduce the input to the gases, we can see how close we can come to the fusion temperature of the ash and how much effect preheating the air has upon the final furnace outlet temperature.

Sometimes the question is asked as to how much the actual furnace temperature is raised by preheating the air for combustion. As a sample calculation, assume the following data:

Lb. coal per hour, 20,000 (13,900 B.t.u. per lb. available for the furnace gases).

Projected area (sq. ft.) radiant heat-absorbing surface in furnace, including boiler tubes, 2000, for a completely water-cooled furnace.

Temperature air without preheating, 70 deg. fahr.

Temperature air with preheating, 470 deg. fahr.

t assumed (saturated steam temperature), 450 deg. fahr.

Input to furnace per square foot (projected area) radiant heat absorbing surface:

$$\frac{20{,}000 \times 13{,}900}{2000} = 139{,}000 \text{ B.t.u. per hour per sq. ft. (projected area).}$$

Value furnace factor r, 0.018 (chart of Fig. 3).

CO_2 (assumed), 14 per cent, lb. gas per lb. coal, 14.65.

T_t (H 0.2825), 3430, no preheat (from Formula 5).

T_t (H 0.292), 3720, with preheat (from Formula 5).

Increase in theoretical furnace temperature, 290 deg. fahr., due to an increase of 400 deg. fahr. in the temperature of the preheated air.

Estimated T_a (H = 0.306), 1780 deg. fahr., no preheat (from Formula 4).

Estimated T_a (H = 0.312), 1920 deg. fahr., with preheat (from Formula 4).

Thus, under the conditions assumed for this example, 400 deg. fahr. increase in the temperature of the air for combustion gives approximately a 290 deg. fahr. increase in the theoretical furnace temperature and only approximately 140 deg. fahr. increase in the actual furnace outlet temperature, which is in accord with the approximate rule that only about one-third of the actual temperature increase in the preheated air appears in the furnace temperature.

Conclusion

The accuracy of the method given in this paper for calculating the temperature of the gases at the outlet of a furnace depends upon the use of the correct value of "r" from the chart of Fig. 3. The method appears simple, almost too simple, but whether it can give the complete picture of the heat absorption in water-cooled furnaces by various curves or families of curves, Fig. 3 for various styles of furnaces, remains to be seen when the performances of many other furnaces have been plotted on this basis.

It is believed, however, that the data available will at least give comparative results, and the purpose of this paper is to present the method only for consideration.

Continuous Weighing with Light-Sensitive Cells

By E. J. WHITE

Engineering Dept., John Chatillon and Sons

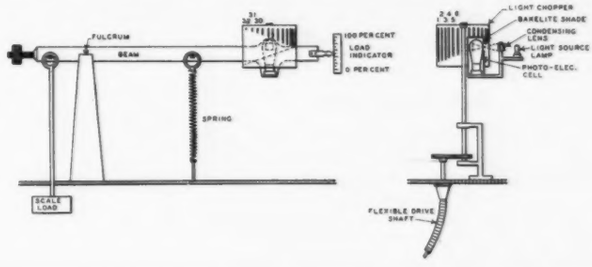
ALTHOUGH electrical means have been employed for some time past in weighing materials in transit on conveyor or feeder scales, it is only recently that the light-sensitive cell has been applied for greater simplicity, handier adjustments and lower cost. Working on the simple idea of interrupting a light beam a varying number of times depending on the momentary weight passing over the scale section, and converting the light impulses into corresponding electrical impulses for the actuation of an electric counter, a marked step ahead has been scored in the weighing art.

In its essentials, the weighing of a continuous flow of material is relatively simple. It is necessary simply to combine the size of the stream with the speed at which it moves. The speed may be constant but the size of the stream may range from zero pounds per foot of movement, to the full capacity of the conveyor. Consequently, any variation of load must be instantaneously noted at the controller so that true integration or totalling of weight may be obtained.

At the point where the continuous stream of material is to be weighed, a short section of belt is mounted in such manner that its varying weight is communicated to the weight checking equipment placed directly above. The varying weight of the load on the conveyor belt section is transmitted directly to the end of the fulcrumed weighing beam, causing this beam to swing over the scale of the load indicator at the far or free end. This of course indicated the instantaneous weight, but there is still need for some device to keep tally of the continuous procession of varying weights. It is at this point that the electric eye or light-sensitive cell gets to work.

Close to the free end of the swinging beam is mounted a cross arm carrying a radiovisor bridge or simplified form of selenium light-sensitive cell, together with a light source lamp. These members are so mounted that one is outside while the other is inside a revolving light-chopper cylinder driven in step with the speed of the belt. The light-chopper cylinder derives its name from the fact that it carries 32 parallel and longitudinal slots which serve to interrupt the passage of the beam of light between light source and bridge. However, the slots are of varying lengths. The first is equal in length to the distance traveled by the scale beam from zero to full load. Each succeeding slot is shortened an equal amount at the bottom, so that a line drawn from the bottom of slot 1 around the cylinder to the bottom of slot 32 would form a true helix, touching the bottom of all slots.

The bridge or cell is mounted in a housing provided with a window directly opposite the sensitive plate. The condensing lens of the light source is adjusted to concentrate the intense beam of light through the window and on to the light-sensitive plate. However, the wall of the rotating chopper cylinder comes between, allowing the light beam to pass only when a slot is in line. Each admission of light reaching the bridge sets up an electrical impulse, which impulse in turn drives the mechanism of the integrator or electric brain that keeps tally, as well as the time chart recorder.



With no load on the belt, the free end of the beam is down, with the focused point of light just below the bottom of slot 1 on the chopper cylinder. Hence no impulses result since no light reaches the bridge. However, as load is placed on the belt, the beam swings upward proportionately, bringing the focused point of light higher and higher on the chopper cylinder, so that more and more slots admit light to the bridge and cause a correspondingly greater number of impulses to actuate the electrical integrator. Thus it will be noted that the number of impulses is always proportional to the load, from zero to the capacity in which the scale is calibrated. At full load there are 32 contacts per revolution of the chopper cylinder. With 350 contacts per min. and a belt speed of 350 ft. per min., an impulse is obtained for each foot of belt, which is representative of a certain weight or amount of material passing over the scale.

The electrical impulses produced by means of the light-sensitive cell, as the result of the interrupted beam of light, are amplified by means of a two stage amplifier. The output operates a vacuum contact relay capable of handling all the current required for the operation of one or more integrators or counters located at any distance from the scale. It is also possible to include time chart recorders, whereby to keep records of load variations throughout the day. A rectifier converts stepped-down a.c. into low-voltage d.c. for the operation of integrators and chart recorders. The integrators are simple electro-magnetic devices somewhat similar to the mechanism of stock tickers, fire alarms, printing telegraphs and so on. The received impulses actuate armatures which are geared with the numeral dials of a register. The integrators are calibrated in short, long or metric tons, pounds, barrels or other desired units.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Barometric Draft Control

Field Sales Corporation have issued a new catalog entitled "Field Barometric Draft Control." This catalog discusses the principle on which this system operates and the field to which it is most applicable. Several actual installations of the system are described and illustrated. 28 pages and cover, 8½ x 11—Field Sales Corp., 5510 Broadway, Chicago.

Belt Conveyors

A very interesting book has been published by The Diamond Rubber Company entitled "How Shall We Handle It?" This book discusses the various problems arising in industrial plants in connection with the conveyance of material and shows the numerous instances in which the Diamond Conveyor Belts have been able to solve these problems. Photographic reproductions showing the various types of applications are included. The economies and advantages of the belt conveyor are listed. 24 pages and cover, 8½ x 11—The Diamond Rubber Company, Inc., Akron, Ohio.

CO_2 Meters

Catalog No. 401 entitled "Republic CO_2 Meters" has just been published by the Republic Flow Meters Company. The Republic Co_2 Meter operates on exactly the same principle as the Orsat apparatus which has been the accepted standard for many years. In this catalog the various types of Republic CO_2 Meters are described in detail together with the principles of operation. A discussion on "What is perfect combustion?" and "Chemical analysis—The basis for all CO_2 measurement," is included. The catalog is very comprehensive and is well illustrated. 24 pages and cover, 8½ x 11—Republic Flow Meters Company, 2240 Diversey Parkway, Chicago, Illinois.

Feed Water Treatment

Bulletin CB describes the Paige-Jones Chemical Balls. These balls are used to charge the Paige-Jones Chemical Ball Feeders. These balls are prepared with different formulas for the different elements which they are to effect. This bulletin also briefly describes the Paige-Jones Ball Feeders, but a more detailed description will be found in Bulletin BF which was reviewed in the January issue of COMBUSTION, 4 pages, 8½ x 11—Paige-Jones Chemical Company, 6216 West 66th Place, Chicago, Illinois.

Furnace Wall Blocks

Bulletin B-341 has recently been issued by the Bernitz Furnace Appliance Company to supersede Bulletin B-34. This bulletin describes the S-100 Bernitz Super blocks for air-cooled furnace walls. These blocks are particularly adapted to furnace walls of stoker fired units. Many illustrations of the various types of blocks and actual applications thereof are included. Tables of dimensions and various curves are shown. 38 pages and cover, 8½ x 11—Bernitz Furnace Appliance Company, 89 Broad Street, Boston, Massachusetts.

Gravity Recorders for Liquids

Bulletin No. 192, just issued by Bailey Meter Company describes Bailey Gravity Recorders for liquids. It illustrates how the Bailey Gravity Recorder continuously records the specific gravity of a liquid and automatically corrects its record for variations in the temperature of the liquid. While this recorder may be used to record the specific gravity of practically any solution, it finds its principal uses in oil refineries, sugar refineries, salt works, textile plants, and paper mills. 8 pages, 7¾ x 11½—Bailey Meter Company, Cleveland, Ohio.

Indicating and Recording Gages

The Hays Corporation have recently issued Catalog PGA-32 entitled "Hays Indicating and Recording Gages." This catalog describes the construction and design of the various Hays Gages. Descriptions of tests conducted are included together with tables, charts and very numerous illustrations. 20 pages, 8½ x 11—The Hays Corporation, East 8th Street, Michigan City, Indiana.

Pressure Recording Controllers

A new Bulletin No. 401 has been issued by the Mason Regulator Company describing its Precision Pressure Controllers. The operating principle on which the design of these controllers is based is described in considerable detail. The individual construction features are described and illustrated. Typical charts showing smoothness of control obtained with the use of Mason Controllers are shown, together with tables of dimensions and a price list. 16 pages, 8½ x 11—Mason Regulator Company, 1190 Adams Street, Boston, Massachusetts.

Refractories

Catalog No. 232 has recently been published by McLeod & Henry Company. This bulletin describes the many types of super-refractory blocks, bricks, and the complete settings made of Carbex, the silicon-carbide refractory developed by McLeod & Henry Company. The physical characteristics and manufacturing processes of Carbex are described in detail, together with a complete explanation of the advantages, limitations, and high-temperature applications for which Carbex is adapted in lining boiler and industrial furnaces, kilns, retorts, muffles, etc. 8 pages, 8½ x 11—McLeod & Henry Company, Troy, New York.

Regulators

The Mercon Regulator is the title of Catalog No. 5 recently issued by The Mercon Regulator Company. The Mercon Regulators differ from all others in that they use the pressure of a liquid column in place of a spring or weight to balance the diaphragm against the pressure of the fluid in the regulator. In this bulletin are described the seven different types of Mercon Regulators together with their fields of application. Photographic reproductions, charts and tables are included. 28 pages and cover, 8½ x 11—The Mercon Regulator Company, 1 LaSalle Street, Chicago, Illinois.

Smothering Fire in Power Plants

A new booklet entitled "Smothering Fire in Power Plants" has recently been issued by Walter Kidde & Company. This booklet describes the method by which the Lux System extinguishes fires in power plants without damaging any equipment. The chemical used in this system is carbon dioxide, which when injected into a burning area snuffs out the fire, as the chemical blankets the flames and thus deprives the fire of its supply of oxygen. 12 pages, 7½ x 10½—Walter Kidde & Company, Inc., 140 Cedar Street, New York.

Steam Turbine Generators

Elliott Company have just issued Bulletin H-7 describing the Elliott Steam Turbine Generators. Elliott Steam Turbines are of the multi-stage axial-flow impulse type. In each stage, the steam expands in the stationary nozzles from a higher to a lower pressure, thus converting a portion of the heat energy to velocity energy, which is absorbed by moving buckets. The construction and design of both the turbines and generators are described in some detail. Many illustrations and charts are shown. 24 pages, 8½ x 11—Elliott Company, Pittsburgh, Pennsylvania.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

The Chemical Technology of Steam-Raising Plant

By Henry Norman Bassett

THIS book describes in logical sequence, the various problems of a chemical nature with which the power-house engineer should be reasonably familiar. It is especially valuable to the man who has had little chemistry. Water softening is discussed; the sources and supplies of water and the character of contaminations are explained. Also discussed are the use of boiler solutions to prevent scale and corrosion and the various methods of preventing corrosion in boilers and their auxiliary equipment. Included are chapters dealing with fuels and their calorific values, together with the composition and the significance of the composition of flue gases, indicators and recording instruments, their use, and value in the operation of boilers. The testing of boilers is given an entire chapter. The book is written mainly from the viewpoint of English practice, but reference is also made to the current American and European continental literature on the subject. The book is the outcome of practical experience and includes information gathered from many sources.

Size of book 8¾ x 5½ in., contains 240 pages, green cloth binding. Price $5.00

Steel Construction

HANDBOOK of the American Institute of Steel Construction. The latest edition of the handbook, issued in January of this year, combines the information contained in their previous publications. Considerable new material has been added, and "the data regarding the new sections recently produced by the rolling mills is complete up to the minute of publication," according to the announcement. The arrangement of the tabular information regarding the Dimensions, Functions, and Allowable Loads for Structural Steel Shapes, has been still further improved. In the Beam Tables, all information including End Reactions and Standard Connection Angles can now be had for any particular beam at one opening of the book. This arrangement also indicates the interchangeability of the shapes rolled by the mills. The table of general contents gives a comprehensive idea of the scope of the handbook, to wit: Part 1, Standard Specifications, A.I.S.C. Code of Standard Practice, History of Steel and Iron: Part II, Properties of Sections, Formulae for Beam Loadings, General Mathematical Tables: Part III, Strength of Materials, General Information: Part IV, Explanation of A.I.S.C. Specification, Rolled Structural Shapes, Built-up Sections, Dimensions, Functions, Allowable Load Tables, Rivets. Contains 450 pages, size of book 8⅛ x 5¼ in., bound in blue keratol, with raised gold letters. Price $2.00.

Hydraulics

By E. H. Lewitt, B.Sc. (London)
(Fourth edition, revised, 1932)

THIS book is primarily a student's textbook. Although written chiefly for the internal and external degrees of the University of London in Engineering, it will be found equally well suited to the syllabuses of other universities and to the examinations for the A. M. Inst. C. E. and the A.M.I.Mech.E.

The book deals from first principles with the theory of hydraulics and its application; no attempt has been made to deal with design problems, which are beyond the scope of the engineering degree. Numerous workedout examples from past B.Sc. examinations of the University of London are included. A number of exercises, with answers, is included at the end of each chapter.

The recent researches on the viscous flow of fluids and the tendency for a more general application of the principle of similarity have rendered it necessary to add a large amount of new matter to the former editions of this book. The whole of the work has been revised. In this edition an attempt has been made to illustrate the theory by giving an account of its practical uses.

The ever-increasing importance of the subject of hydraulics to the engineer makes the choice of a thoroughly reliable textbook essential.

The following chapter headings give a comprehensive view of the scope of this book: Static Pressure of a Fluid; The Buoyancy of a Liquid; Orifices and Mouthpieces; Notches and Weirs; Friction and Flow Through Pipes; Flow Through Open Channels; Reciprocating Pumps; Impact of Water; Water Turbines; Centrifugal Pumps; Viscous Resistance of Fluids; Hydraulic Machines, Meters and Valves.

The book contains numerous illustrations and diagrams; at the back of the book, a summary of formulas, useful tables and data. Size of book, 8½ in. x 5½ in.; 384 pages, cloth binding; price $3.00.

NEW EQUIPMENT

of interest to steam plant Engineers

Seamless, Flexible Metallic Tubing

A seamless, flexible metallic tubing, which, it is claimed, will find an important place in practically every industry, has just been placed on the market by the Bendix Aviation Corporation.

The new product can be effectively used in any of these general applications: Fluid connections between moving parts; absorption of vibration and conveyance of liquids, semi-liquids, steam or gas. Machinery installations can be simplified by eliminating clumsy bends in piping while maintenance is reduced materially because the tubing eliminates slip and ball joints, thus reducing packing and shutdown costs. Likewise, replacement due to wear or deterioration is reduced to an absolute minimum.

The Bendix hose has been applied to such widely varied uses as lubrication, gum manufacture, electric wiring conduits, automobile exhaust pipes, radiator hose, shielding airplane radio, hydraulic and airbrake systems and oil burners. It has withstood pressures of 10,000 pounds

Fig. 1

to the square inch and temperatures of over 500 degrees.

The hose is seamless from the tip of one fitting to the tip of the fitting at the opposite and because the fittings are brazed or welded, forming an integral part of the hose. This construction prevents leaks developing in the hose and breaks occurring between the hose and its fittings, as frequently happens with interlocked or locked joint metal tubing.

Made of special bronze alloy seamless pipe, the Bendix hose is corrugated in round-thread single lead deep wall form and does not contain welded, brazed or interlocked joints. Engineers claim the Bendix hose is far more flexible than existing types of metal hose because of its "deep wall" construction. (See Fig. 1.)

A protective casing, braided from copper is designed to cover the hose with either one, two or three layers, depending on the pressure the hose must withstand. As a protection against mechanical damage to the braid covering and to distribute the flexing action, the manufacturer recommends use of an interlocked, unpacked galvanized steel casing over all. (See Fig. 2.)

The new product is being made by the Bendix Stromberg Carburetor Company, subsidiary of the Bendix Aviation Corporation at South Bend, Ind., and orders for 3,000,000 feet for 1932 delivery have

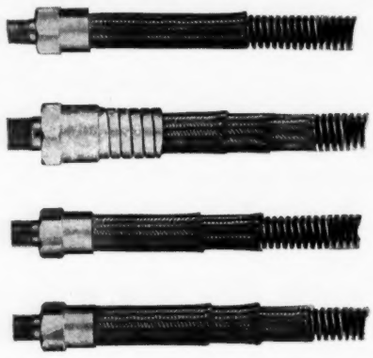


Fig. 2

been received prior to formal announcement.

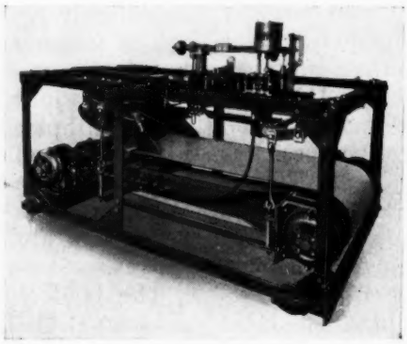
The hose is being manufactured at present with internal diameters of 3/16, 1/4, 3/8, 1/2, 3/4 and 1 inch, but engineers declare it can be made in practically any size desired.

Robotized Conveyor Scale

John Chatillon & Sons of New York have developed and recently placed on the market the Telepoise Feeder and Conveyor Scales. The illustration of this mechanism shows one of a number furnished a large public service corporation.

The "Electric Eye" or light sensitive cell is the heart of this unit. This photoelectric unit, a product of the Burgess Battery Company, is employed in conjunction with a simple and ingenious invention of the scale manufacturer to convert electric impulses into pounds, barrels, short, long or metric tons. By this invention it is possible to control the amount of coal fed to stokers and at the same time weigh it.

One of the numerous advantages claimed for this invention is the elimination of parts subject to wear, adjustments



and replacements. This mechanism is positive and instantaneous in operation. The weigh beam and levers are not employed as prime movers for any device. They are free to indicate accurately the weight which in turn is electrically transmitted to a register, indicator or recorder, or a combination of any two or all three of these instruments.

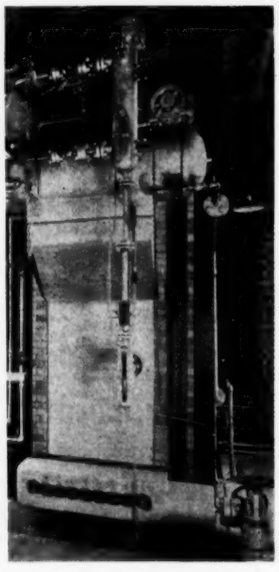
The Telepoise scales are available with positive automatic control so that there is no possibility of the occurrence of a down-spout or the emptying or overflowing of either bin or hopper.

Eye-Line Water Level Indicator

The Yarway Eye-Line Water Level Indicator has been developed and placed on the market by the Yarnall-Waring Company, Philadelphia, Pa.

This indicator employs as the actuating mechanism the same floatless principle with the displacement weights used in the Yarway Hi-Lo Alarm Water Column. A stainless steel tube extends down from the water column to the boiler room level, where a standard Yarway Flat Glass Gage prominently displays a movable plunger or target indicating to the furnace attendant the water level in the boiler. This plunger is connected by a stainless steel or monel chain with the actuating balanced weights in the auxiliary column. The position of the target shown through a Yarway Flat Glass Gage duplicates the exact position of the water level above.

At this distance below the water column, water in the connecting tube and gage is relatively cool—hence no erosion of gage



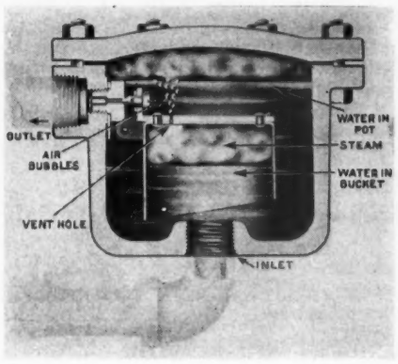
glass and no need for mica protection with resulting much clearer vision. Since the Water Level Indicator is practically at room temperature the difficulty with flat glasses at high temperatures is eliminated. Sediment is negligible, as the sediment chamber in auxiliary column prevents its entrance into the tube. Even if water in gage should become cloudy, a slight opening of drain at bottom of gage will immediately clear the water.

In order that the operator, when he comes on his shift, may be quite sure that his water level gages are accurately responding to the boiler water level, he can operate the drain valve X, which will immediately reduce the water level in the column, thus allowing the upper as well as the lower Eye-Line Indicator to respond to the artificially changed water level.

Inverted Open Float Steam Trap

After having submitted its Inverted Open Float Steam Trap to many exhaustive service tests and having found the trap entirely successful the Crane Company, 836 So. Michigan Avenue, Chicago, is now offering it to the trade.

This trap was developed as the result of a demand for a small inexpensive yet



very efficient unit for draining small steam heated apparatus used in industrial plants. With this in mind the design developed includes all those requisites necessary in a successful steam trap as, simplicity, materials giving long life to all working parts, low first cost and very low maintenance cost.

The operation of this trap is as follows: The inlet is at the bottom. Condensation flows upward into the body of the trap. Since the valve is at the top, the body of the trap must be full of water before any condensate can be discharged. The discharge is continuous until no more condensation enters the trap. Steam then enters the float and displaces the water contained therein to a point where the float becomes buoyant and rises. This closes the valve and stops further discharge. The float remains buoyant, until condensation enters and replaces the steam. The float then sinks and opens the valve.

The cycle of operation is practically instantaneous and eliminates any chance for wire drawing the valves. It will be observed from the sectional views, that as the steam must first enter the float, steam does not escape through the discharge opening. This adds greatly to the economy of the trap.

Air or any other non-condensible gas entering the float passes through the small vent hole in the top of the float and collects in the upper part of the trap. When the trap operates the first thing to be discharged is this air or gas.

These traps will air bind. No by-passes, thermostats, air vents or pet cocks are necessary.

Cooling leg on inlet of trap is necessary as trap will give maximum discharge with condensate at any temperature.

Lock-Forged Construction

Alco Products, Inc., New York, has recently developed a new lock-forged construction applicable to tubular heat exchange apparatus.

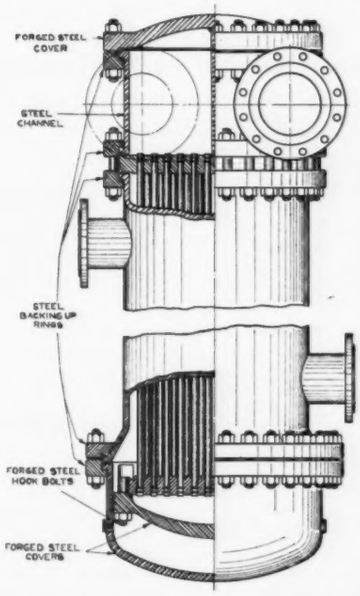
This construction is particularly applicable to service in which high pressures and high temperatures are met. All the metal comprising the pressure-resisting structure of Lock-Forged units is either rolled or forged. The bolted joints are in every case heavily reinforced and do not depend on any weld. They are capable of withstanding enormous stresses and can be pulled up on the gaskets until there is no possibility of a leak.

Both shell and channel are welded steel cylinders. A narrow flange is formed on the ends by rolling and upsetting the metal in a massive flanging machine. The flanges thus formed are the bearing surfaces for the Lock-Forged joints and are finished by machining all over.

Flanges are stiffened and supported by loose, rolled steel backing up rings which are machined on all bearing surfaces and which are either drilled for bolts or provided with a groove on the back side for hook bolt bearing. All bearing surfaces of the joints are recessed by overlapping of the cover or of the backing up ring. The metal gaskets are thus centered and cannot be blown out.

Shell cover and floating head cover are attached by means of high strength forged steel hook bolts. In breaking the joints these hook bolts can be released without necessity of backing off the nuts more than a few turns.

Covers are formed from flat steel plates in a hydraulic flanging press. Both in forming the flanges and in pressing out



the covers the metal is worked at forging temperature after which it is normalized thus assuring a uniform close-grained structure throughout.

Corrugated Expansion Joint

A new corrugated type of expansion joint has been developed and placed on the market by the E. B. Badger & Sons, Company, Boston, Massachusetts. This joint operates on the principle of directed flexing of the corrugations.

When in operation the movement of the corrugation flows back and forth over the curved surface of the equalizing ring, distributing the stresses uniformly throughout the entire corrugation. The movement can be said to be undulating, an action that can actually be seen in the joint with the ring cut away. The movement is equalized at all times because it cannot stop at any point and build up stresses. It is directed because the matched contours of the ring and of the corrugation force the flexing member to assume the correct position at all times.

Everdur is the new metal selected for Badger Expansion Joints. It has a 96 per cent copper base, with 3 per cent silicon and 1 per cent manganese, which gives a metal having all the advantages of copper, plus a much greater resiliency and

durability and with tensile strength of mild steel. Other features claimed for this joint are—absence of maintenance because no packing is used—compactness and ease of installation—monel sleeve for use with superheated steam—choice of welding end or flanged end joints.

Non-Recording Pressure Controller

The Mason Regulator Company of 1190 Adams Street, Boston, Mass., have placed on the market the Mason Pressure Controller, (non-recording type).

The Mason Controller is a compact self-contained unit. Two control pressure gages are enclosed; one indicating the pilot valve supply pressure and the other the pressure to the diaphragm of the control valve.

The heart of this instrument is the fully balanced compound pilot valve which permits it to be used for remote control service. Further developments consist of simplification in the methods of adjustment, such as the pressure setting of this controller which can be quickly changed by merely turning the knurled thumb nut at the bottom of the case.

Another feature of this Mason Controller is the ease with which it may be changed from back pressure to reducing service. This can be done by any plant operator in a few minutes with a screw

driver. The same change may be made to convert the controller from use with a direct acting control valve to service with a reverse acting one or vice versa.

The special field of application for which this controller was designed is the process industries.

A descriptive bulletin No. 401 may be obtained from the manufacturer.

BOOKS

1—Refractories

By F. H. Norton

594 Pages, illustrated, 6 x 9 in. Price $6.00

Since its review in the March issue, has created considerable interest. The book is a comprehensive treatise on refractories used in the construction of all types of furnaces, embodying the history, the mining and preparation, fabricating, testing and specific uses of the refractories in general use. The descriptions of the manufacturing processes have been confined to American practice. An important feature is the inclusion of much first-hand data which the author obtained from manufacturers of refractories.

This book should be of unusual value to the student, the user and tester of refractory materials as well as to those having to do with the operation of glass, chemical, power or metallurgical plants. Exceptionally well illustrated with photographs, tables and curves and numerous photomicrographs.

2—American Gas Practice (A Textbook)

By Jerome J. Morgan

969 Pages, 6 x 9 in. 250 Illustrations Price $8.00

This is the second edition of Volume 1 originally issued as "Manufactured Gas" although the content has not been changed materially. Considerable new material however has been introduced in this second edition, including four new chapters on Natural Gas, Reforming of Hydrocarbon Gases, Liquefied Petroleum Gases in Gas Production and Gas Conditioning. Further new sections have been added, or extensive additions made to existing sections. The book is strongly recommended as a reference volume on the subject.

3—Symposium on Welding

A. S. T. M.

152 Pages Price $1.75

The eleven papers presented in a Symposium on Welding held at the second Regional Meeting of the American Society for Testing Materials, Pittsburgh. Included, in addition to the papers presented, are the discussions on processes, materials, applications, inspection and testing; tests by stethoscope, magnetic action, X-ray, fatigue and impact. The book covers newer processes for steel and alloys by gas and electric arc, types of joints, fusion welding and specifications. The characteristics of good and bad welds are described and actual inspection practice is taken up in detail. Bound in cloth. Contains many photographs, tables and diagrams.

4—Proceedings of Third International Conference on Bituminous Coal

Two volumes, approximately 800 pages each size 6 x 9 in. Full cloth. Price per set of two volumes $15.00

The books are regarded as standard reference works on fuel technology. Contain the proceedings of the Third International Conference on Bituminous Coal which was held under the auspices of the Carnegie Institute of Technology, covering all papers and discussions delivered at the four-day meetings. Contributions of scientists from ten foreign countries have been translated into English. Included in the Proceedings are 98 papers. Illustrations and graphs are incorporated.

5—Materials Handbook

By George S. Brady

Second Edition, revised and enlarged
600 Pages 5½ x 7½ inch. Price $5.00

Here in encyclopedic form and volume is the up-to-the minute information on thousands of engineering materials needed by the product engineer, purchasing agent and factory executive. In handy, complete form it points a clear way among the new alloys, synthetic resins, industrial chemicals, the many materials both new and old, used in manufacturing and engineering. Arranged and indexed for instant reference. It is a book which will be consulted frequently by every person who has access to a copy.

6—1931 A.S.T.M. Proceedings American Society for Testing Materials

In two parts

Part one, 1119 Pages
Part two, 1027 Pages

Price, each part:		
	Paper binding	$5.00
	Cloth "	6.00
	Half leather "	7.00

Proceedings of the Thirty-fourth Annual Meeting held at Chicago, June 22-26, 1931, Vol. 31, just issued in two parts, both parts containing more than 2100 pages. Part one contains the Committee Reports, part two contains the technical papers presented.

7—Combustion in the Power Plant (A Coal Burner's Manual)

By T. A. Marsh

255 Pages Price $2.00

The author's discussion of coals and combustion is simple and understandable. His consideration of equipment—stokers, boilers, furnaces, fans and auxiliaries—is thoroughly practical. He tells how to select a stoker for the best available coal; how to design furnaces and arches; how to analyze draft problems and design chimneys, gas flues and boiler passes; how to purchase coal and calculate steam costs. In short, he gives to every phase of his subject a practical interpretation that makes this book of exceptional value to men actually identified with steam plant design and operation.

8—Handbook of Oil Burning

By Harry F. Tapp

629 Pages Price $3.00

Contains information of practical value to the engineer or contractor whose work requires a knowledge of oil burning heating or power equipment. Covers comprehensively the industrial application of oil as fuel, with drawings, illustrations and tables of this style of installation. Also discusses the various types of oil burner and principles of construction, oil burner controls and motors and fuel tanks and storage. Contains also a wealth of general information such as the chemistry of combustion and flame, fundamentals of heat and heat transfer, the determination of heating capacity requirements and comparative fuel costs.

9—The Problem of Fluctuating Loads on Boilers

By G. E. Hider

115 Pages Price $3.00

The subtitle of this book is "An Investigation into the Characteristics of Different Types of Boilers, their Effect on Production Costs, and the Influence of Thermal Storage Systems." The book stresses the importance of *water content* as a factor in boiler efficiency, a matter frequently overlooked in other books on the subject. It is pointed out that under conditions of rapidly fluctuating load such as obtain in many industries, the quantity of steam delivered into the main is often far less than that corresponding to the feedwater entering the boiler and that the difference is a function of the water content of the boiler. This book should be of interest to engineers in large and small plants.

Gas and Oil Engines

10. **AMERICAN DIESEL ENGINES,** *by L. H. Morrison.* Comprehensive discussion of all present-day Diesel engines built in the United States. 606 pages. Price $5.00.
11. **HIGH SPEED INTERNAL COMBUSTION ENGINE,** *by Harry R. Ricardo.* Thoroughly revised and covering every detail of design. Recognized as an authority and practical reference. 435 pages. Price $12.00.
12. **DIESEL ENGINE OPERATION, MAINTENANCE AND REPAIR,** *by Chas. H. Bushnell.* Treats of fundamental principles rather than details of design which are constantly changing. 282 pages. Price $3.50.

Fuels and Combustion

13. **AMERICAN FUELS,** *by Bacon and Hamer.* (2 vols.) The whole subject of the characteristics and economic utilization of fuels of all kinds exhaustively treated. 1245 pages. Price $12.00.
14. **BURNING LIQUID FUEL,** *by W. N. Best.* A practical treatise on the combustion of oils and tars. 341 pages. Price $4.00.
15. **COAL,** *by Elwood S. Moore.* Coal, its properties, extraction, uses and distribution. 462 pages. Price $5.00.
16. **GAS AND FUEL ANALYSIS FOR ENGINEERS,** *by A. H. Gill.* A concise presentation of the methods of analysis used in testing the efficiency of a boiler plant. 181 pages. Price $1.75.
17. **GASEOUS COMBUSTION AT HIGH PRESSURE,** *by Bone, Newitt and Townsend.* The experimental studies presented consist chiefly of hydrogen-air, carbonic oxide-air and methane-air explosions at various initial pressures between three atmospheres and two hundred atmospheres. 807 pages. Price $7.50.
18. **HEAT LOSS ANALYSIS,** *by E. A. Uehling.* Gives the operating personnel of the boiler room understanding of the processes of combustion and heat absorption. 240 pages. Price $2.50.

General Engineering and Mathematics

19. **APPLIED CALCULUS,** *by F. F. P. Bisacre.* A textbook providing an introductory course in the calculus for the use of students of natural and applied science whose knowledge of mathematics is slight. 460 pages. Price $3.75.
20. **EXPERIMENTAL MECHANICAL ENGINEERING** (Vol. I, Engineering Instruments) *by Diederichs and Andrae.* Covers the construction, use and calibration of engineering instruments. 1982 pages. Price $8.00.
21. **MATHEMATICS FOR ENGINEERS,** *by R. W. Dull.* A mature treatment of mathematics for practicing engineers. 780 pages. Price $5.00.
22. **MECHANICAL ENGINEERING LABORATORY PRACTICE,** *by Shoop and Tuve.* Will serve as a valuable reference book for those engaged in experimental work in this field. 490 pages. Price $4.00.

Handbooks and Encyclopedias

23. **CONDENSED ENCYCLOPEDIA OF ENGINEERING.** The essential facts about thousands of standard and special subjects allied to engineering, mechanics, mechanical equipment and materials, shop and factory operation. 1242 pages. Price $6.00.
24. **ENGINEERS VEST POCKET BOOK,** *by W. A. Thomas.* A handy pocket size reference book which provides a variety of useful information for the engineer, principally in the form of tables, charts and formulas. 224 pages. Price $3.00.
25. **A HANDBOOK OF ENGLISH IN ENGINEERING USE,** *by A. C. Howell.* Here is a real up-to-the-minute handbook that should be on the desk of every technical writer. Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing and grammar. Examples cover letters, reports and technical articles. 308 pages. Price $2.50.
26. **HANDBOOK OF OIL BURNING,** *by Harry F. Tapp.* Contains information of practical value to the engineer or contractor interested in oil burning heating or power equipment. 629 pages. Price $3.00.
27. **HANDBOOK OF PIPING,** *by Walker and Crocker.* Authoritative and accessible data for the engineer interested in piping work. 755 pages. Price $5.00.
28. **WHO'S WHO IN ENGINEERING** (3d edition 1931) *W. S. Downs, M. M. Lewis, editors.* This is the third edition of this valuable directory of engineers. Contains 1600 pages. Price $10.00.
29. **MECHANICAL ENGINEERS HANDBOOK,** *by R. T. Kent.* A complete library of engineering practice. Designer, power plant engineer, shop superintendent, heating and ventilating engineer, hydraulic engineer, building constructor, foundryman, automotive engineer, will find this a complete reference book. 2247 pages. Price $6.00.
30. **MECHANICAL ENGINEERS' HANDBOOK,** *by Lionel S. Marks.* The third edition of this great reference book has been thoroughly revised in all parts, bringing it up to date in both practice and theory. Important new sections include vibration problems—refractories, high temperature carbonization of coal and gas making—low-temperature carbonization of coal—industrial combustion furnaces—electric industrial furnaces. 2265 pages. Price $7.00.

Steam Engineering and Thermo-Dynamics

31. **ELEMENTARY STEAM POWER ENGINEERING,** *by E. McNaughton.* Discussion of the fundamental principles underlying construction, operation and testing of steam power plant equipment. 590 pages. Price $5.00.
32. **ENGINEERING THERMODYNAMICS,** *by C. E. Lucke.* Enables engineers, draftsmen and managers to get a numerical answer to every-day problems of design and performance of heating, refrigerating and power apparatus. 1176 pages. Price $8.00.
33. **HEAT POWER,** *by Norris and Therkelsen.* Intended to serve as an introductory course in the principles of heat power for students in engineering. 376 pages. Price $3.50.
34. **HEAT TRANSMISSION IN BOILERS, CONDENSERS AND EVAPORATORS,** *by R. Royds.* Deals with problems involving the design and operation of boilers, condensers and evaporators. 302 pages. Price $6.00.
35. **PRACTICAL HEAT,** *by Terrel Croft.* A book on heat and the practical applications of heat which anyone with a working knowledge of arithmetic can use intelligently. 695 pages. Price $5.00.
36. **STEAM AND GAS ENGINEERING,** *by Thomas E. Butterfield.* A recognized textbook covering fuels and their combustion, steam power engineering, the gas laws, internal combustion and engineering problems of heat power. 481 pages. Price $4.50.
37. **STEAM TABLES AND MOLLIER DIAGRAM,** *by Joseph H. Keenan.* These new Steam Tables, extending to a pressure of 3500 lb. per sq. in. and a temperature of 1000 deg. fahr., were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A.S.A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23" x 34") is also included. Price $2.00.

Steam Plant Design, Operation and Equipment

38. **A. S. M. E. BOILER CONSTRUCTION CODE (1931 COMBINED EDITION).** Contains the latest specifications formulated by the A. S. M. E. Boiler Code Committee covering construction of power, low-pressure heating, locomotive and miniature boilers, also unfired pressure vessels, rules for inspection and the latest material specifications used in the construction of boilers; also the rules covering the fusion process of welding. Contains a comprehensive index. 576 pages. Price $5.00.
39. **BOILER FEEDWATER PURIFICATION,** *by S. T. Powell.* Basic facts concerning feedwater treatment to assist the designing engineer in the selection of proper form of treatment. 363 pages. Price $5.00.
40. **DRAFT AND CAPACITY OF CHIMNEYS,** *by J. G. Mingle.* The most authoritative book ever published on the subject. 339 pages. Price $3.00.
41. **ENGINEERING OF POWER PLANTS,** *by Fernald and Orrok.* A standard test and reference book. 663 pages. Price $5.50.
42. **EXHAUST STEAM ENGINEERING,** *by C. S. Darling.* The book is of special value as a handbook for the solution of steam plant problems. The subject matter will be as useful in the renovation of old plants as in the design of new ones. 431 pages. Price $7.50.
43. **FUEL ECONOMY IN BOILER ROOMS.** *by Maujer and Bromley.* Covers principles of combustion, coal and flue gas analysis, calculations involved in determining boiler efficiency. 308 pages. Price $3.00.
44. **FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS,** *by H. B. Cochrane.* As a handbook on fuels, combustion, heat absorption, boilers and feed-water, this volume is eminently practical and useful. Every steam plant engineer should have a copy. 808 pages. Price $3.00.
45. **HEAT ENGINES** (4th Edition), *by John R. Allen and Jos. A. Bursley.* An excellent textbook for the student engineer, also the practical engineer. In this new edition particular attention has been given to the progress made in boiler room practice and equipment and the new developments in the field of the internal combustion engine. 540 pages. 6½ x 9½ in. Price $4.00.
46. **POWER PLANT LUBRICATION,** *by W. F. Osborne.* A practical book for the power plant engineer explaining the physical and chemical properties of lubricants, their action under changing influences of heat, pressure, etc., and the methods of determining their relative value. 275 pages. Price $3.00.
47. **STEAM TURBINES,** *by E. F. Church.* A concise text on steam turbines. 273 pages. Price $3.00.

Metal Properties and Characteristics

48. **CORROSION CAUSES AND PREVENTION,** *by F. N. Speller.* A systematic presentation of the available information on the corrosion problem. 621 pages. Price $6.00.

COUPON

IN-CE-CO. PUBLISHING COMPANY, 200 Madison Ave., New York, N.Y.

Enclosed find check for $..... for which please send me the books listed by number

NAME _____ **Books Nos.** _____

ADDRESS _____

Postage prepaid in the United States on all orders accompanied by remittance or amounting to five dollars or over.

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 282 boilers were placed in January according to reports submitted to the Bureau of the Census by 72 manufacturers.

Month	1931 Number	1931 Square feet	1932 Number	1932 Square feet
January	598	576,723	282	267,268
February	516	622,343		
March	630	664,784		
April	689	825,203		
May	658	603,401		
June	818	677,434		
July	816	687,058		
August	827	594,698		
September	893	692,238		
October	672	467,375		
November	491	424,044		
December	409	394,317		
Total (Year)	8,017	7,229,618		

NEW ORDERS, BY KIND, PLACED IN JANUARY, 1931-1932

Kind	January, 1931 Number	January, 1931 Square feet	January, 1932 Number	January, 1932 Square feet
Stationary: Total	551	523,624	271	231,981
Water tube	62	263,852	26	107,652
Horizontal return tubular	36	50,734	27	27,996
Vertical fire tube	59	15,194	34	7,038
Locomotive, not railway	7	4,250	3	2,864
Steel heating	355	169,907	163	74,950
Oil country	3	1,969	...	.....
Self contained portable	22	11,292	17	11,061
Miscellaneous	7	6,426	1	420

MECHANICAL STOKER SALES

January stoker sales, reported to the Bureau of the Census by the 55 leading manufacturers, totaled 113 stokers of 247,812 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1930						
January	53	13,198	24	2,872	29	10,326
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	66	13,849	37	5,326	29	8,523
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
August	128	29,971	59	8,318	73	21,653
September	96	22,462	56	8,720	40	13,742
October	83	20,339	47	6,566	36	13,773
November	62	13,231	38	5,995	24	7,236
December	48	11,072	32	4,903	16	6,169
Total (Year)	988	247,812	510	77,391	478	170,421
1932						
January *	113	34,142	70	10,306	43	23,836

* Preliminary.

PULVERIZED FUEL EQUIPMENT SALES

January orders for coal pulverizers as reported to the Bureau of the Census aggregated 7 pulverizers having a total capacity of 29,600 lb.

Year and Month	STORAGE SYSTEM: PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	STORAGE SYSTEM: BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM: PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	DIRECT FIRED OR UNIT SYSTEM: BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1932														
January	..	..	..	.....	..	.....	.....	7	5	2	29,600	6	30,798	268,750
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1932														
January	..	..	..	.....	..	.....	.....	2	2	..	2,750	..	.....	.....